

4. Description of Remediation Modules

This chapter assembles the general response actions and technologies retained from Chapter 3 into modules designed to address the contaminants and media identified in Chapter 1, and to meet the RAOs presented in Chapter 2. For each area we present from three to eight remediation modules; one or more of these modules will constitute the alternatives presented in Chapter 6. After public review and comment, the DOE will present selected remedies in an Interim Site-Wide Record of Decision.

4.1. Approach and Assumptions

The following sections describe the general approach and assumptions regarding the remedial technologies and cost estimates presented in the modules.

4.1.1. Approach

1. Remediation modules are presented for release sites when triggered by any of the following four criteria:
 - a) Ground water and/or surface water is currently contaminated at concentrations above background.
 - b) Contaminants are present in the vadose zone, surface soil, or buried waste in concentrations sufficient to potentially contaminate, or to continue to contaminate, ground water to concentrations above background.
 - c) A human health risk greater than 1×10^{-6} , or a HI greater than 1 is present, either from a single pathway and contaminant, or additively as the sum of risks or hazards present from all pathways and contaminants. Ingestion of ground water is not included in this criterion, because inclusion of an active ground water remediation module is triggered by criterion (a), regardless of risk or hazard.
 - d) The ecological Hazard Index exceeds 1 for the San Joaquin kit fox. The kit fox is used as a surrogate for sensitive predatory fossorial species.
2. The modules are not designed to stand alone. For a specific OU or release site, combinations of modules will comprise the alternatives.
3. The modules are conceptual in scope, and are intended to facilitate comparison of remedial strategies, rather than to provide design information. The DOE will present more detailed information to support the implementation of the selected remedies in future documents. That information will include remedial designs, monitoring programs, and contingency plans.
4. A number of technologies are retained, particularly those for *ex situ* treatment of extracted ground water or soil vapor, for use at a later stage in the remedial design process. However, these technologies are not specifically included in modules. The default treatment technologies described in Section 4.1.2 were used for estimating costs.

5. Remediation modules are presented for all COCs for which sufficient data are available to support conceptual remedial design.

The following sections describe the assumptions regarding the technologies used to assemble the modules. Appendix D contains the detailed assumptions used to estimate costs.

4.1.2. Assumptions

4.1.2.1. No Further Action

1. DOE will not be required to perform further investigation, monitoring, reporting, or risk management.
2. The only media for which no further action modules are presented are surface soil or subsurface soil/bedrock. DOE assumes that ground water and surface water monitoring modules will be required, regardless of whether or not an active remedy is implemented.
3. COCs are only considered for no further action where no risk greater than 1×10^{-6} or a HI of 1 is present.
4. There are no costs associated with the no further action modules.

4.1.2.2. Monitoring

Although not considered a ground water response or remedial technology, monitoring is included for planning purposes.

1. Monitoring is defined as the routine, periodic, baseline sampling and analysis of contaminated media not associated with the operation and optimization of remediation systems. Every five years, physical surveys of plant and wildlife communities will be conducted at Site 300 to determine species composition for the purpose of identifying new species of potential concern (i.e., rare, threatened or endangered) that may be at risk from contaminants at Site 300. Should such species be determined to be present in areas of contamination at Site 300, the appropriate regulatory agency will be consulted (i.e., USFWS), and a preliminary screening assessment will be conducted as required.
2. In most cases, monitoring will consist of collecting ground water samples from existing monitor wells and surface water bodies. Collecting water or vapor samples from extraction wells is not included in monitoring modules, but is included in extraction and treatment modules.
3. The sampling frequency is assumed to be quarterly.
4. The water level measurement frequency is assumed to be quarterly.
5. Analyses will include all COCs.
6. To estimate costs, we assume that monitoring will be performed for a period of 30 years.

The following activities are included in all monitoring modules, as appropriate to that release site or OU:

1. Measure ground water levels.

2. Perform ground water sampling and analysis.
3. Maintain monitor wells.
4. Conduct surface water sampling and analysis.
5. Inspect surface conditions of waste sites, and if potential disruption is visible, present plans for protecting the site.
6. Manage, analyze, and present data.

4.1.2.3. Risk and Hazard Management

1. The overall goal of risk management is to ensure that the RAOs identified in Chapter 2 are achieved.
2. Risk and hazard management is included as a module where the risk at any exposure point exceeds 1×10^{-6} , and the HI is greater than 1, exclusive of ingestion of ground water. Measures to prevent ingestion of ground water are included in risk management modules wherever ground water contamination exists above concentrations protective of human health, as established in the RAOs.
3. Administrative controls are the basis of most risk management modules. The DOE will implement these measures to ensure that the selected remedy is protective of human health. Site 300 access is currently restricted by fencing and a full time security force. Building occupancy and land use are controlled by Site 300 Management. Therefore, only risk and hazard management measures that supplement existing controls are included. Land-use restrictions would include controls on installing water-supply wells, where applicable, to prevent establishing complete exposure pathways for ingestion of contaminated ground water.
4. It is assumed that Site 300 will remain under the control of the DOE indefinitely, and that the access restrictions to the site (fencing, security patrols) currently in place will continue for the foreseeable future. All remedies would be reevaluated if any transfer of ownership or change in land use is anticipated. DOE will meet its commitments in the Site 300 FFA, Sections 28 (Transfer of Real Property) and 37 (Facility Closure), regarding its cleanup obligations of property ownership changes in the future.
5. During remediation, DOE will implement a formal risk and hazard management program which will include periodically: (1) collecting additional environmental samples at locations where a human health risk is above 1×10^{-6} , or a HI greater than 1 has been identified in the baseline risk assessment, (2) reviewing exposure pathway-related conditions, such as building occupancy and land use, (3) refining the risk and hazard models using current data, and (4) reporting the results to the stakeholders. A set of standard sampling conditions such as time of year, range of acceptable temperatures, and wind speed will be developed to minimize variability in ambient air and surface soil samples.
6. The Site 300 Contingency Plan (CP) will include actions to be implemented in the event a remedy does not achieve RAOs or comply with ARARs, or if any new contaminants are found for which the remedies proposed in this document and the Proposed Plan are not

adequate to achieve RAOs. The CP will contain the standard procedures (e.g., an Explanation of Significant Difference (ESD), or a ROD amendment) necessary to implement changes to the Interim ROD. The CP will also address possible property transfer or change in land use. The Site 300 CP will also address situations where the existing access restrictions are removed or relaxed.

As part of the LLNL program to mitigate impacts to wildlife, biologists will monitor those areas in which the relevant ecological HI exceeds 1. Currently, the only threatened, endangered or species of special concern which may be potentially exposed to unacceptable levels of contaminants are predatory fossorial species (i.e., the San Joaquin kit fox). Thus, areas where the ecological HI for the San Joaquin kit fox exceeds 1 will be monitored. Should kit fox or other predatory fossorial species of special concern to wildlife agencies be found in these areas, DOE will consult with the appropriate wildlife agency to develop response actions, such as monitoring or animal relocation. An exception to this is for areas where PCBs/CDDs are present in surface soil. These areas will be monitored for the presence of any threatened, endangered or species of special concern. In addition, biologists will monitor Site 300 for the presence of sensitive species not previously identified. The life history of these species will be reviewed to determine the potential for unacceptable exposure to contaminants present at the site. Should it be determined that species do have a potential risk of exposure, their presence in areas where relevant HIs exceed 1 (such as those for ground squirrels or deer) will be determined.

The following activities are included in all risk and hazard management modules, as appropriate to that release site or OU:

1. Implement institutional controls to manage risks:
 - Establish building occupancy and/or land use restrictions to ensure that the risks and hazards estimated in the baseline risk assessment are not exceeded due to changing conditions at the site, and that the remedy remains protective of human health and the environment; and
 - Erect warning signs to ensure compliance with area access restrictions and site-specific building occupancy and land use restrictions.
2. Develop and implement a risk and hazard monitoring and assessment program:
 - Collect and analyze air, water, or soil samples to determine current exposure concentrations of COCs;
 - Where applicable, conduct wildlife surveys by biologists to evaluate the presence of the San Joaquin kit fox or other fossorial vertebrate species of special concern and, if found, consult with the appropriate wildlife agencies to develop response actions such as monitoring or animal relocation, and evaluate the presence of new species of special concern;
 - Integrate these data into risk assessment calculations to determine any changes in risks and hazards; and
 - Review these data to evaluate compliance with RAOs.
3. Develop and implement Operational Safety Procedures for all remedial actions where risks or hazards can be foreseen.

4.1.2.4. Monitored Natural Attenuation

1. This module is included to address COCs in ground water only where: (a) there are no current or projected unacceptable risks, (b) the source has been removed or contained, or is already depleted, and (c) data indicate that the plume contours are static or retreating.
2. The scope is more extensive than a monitoring-only module, addressing those situations where MNA is being considered as a final remedy.
3. Any source control measures that would be required to implement MNA are presented in other modules (e.g., landfill excavation or capping).
4. Costs in addition to monitoring only would include modeling to predict the spatial distribution of contaminants over time and demonstrate the efficacy of MNA, and planning an adequate monitoring network, to include background, performance, and guard wells. Contingency criteria and potential responses will be included in the Site CP.

The components of MNA are described in detail in Section 3.2.3.

The following activities are included in MNA modules:

1. Measure ground water levels.
2. Perform ground water sampling and analysis.
3. Maintain monitor wells.
4. Conduct surface water sampling and analysis.
5. Manage, analyze, and present data.
6. Perform contaminant fate and transport modeling.
7. Install additional monitor wells, if required.

4.1.2.5. Ground Water and/or Soil Vapor Extraction and Treatment

1. Ground water extraction is included as a module for any release site where ground water has been contaminated in concentrations above background. The exception is tritium, because no effective *ex situ* treatment technology is available.
2. The objectives of ground water extraction are site-specific, but may include (a) reducing contaminant concentration and mass, (b) controlling plume migration, (c) reducing risk or hazard posed by potential exposure, and/or (d) restoring beneficial uses of ground water.
3. For cost estimating purposes, an estimate was used of the maximum probable number of extraction wells needed to achieve remedial objectives for each alternative. This was estimated by integrating available information including ground water monitoring data, hydraulic test results, capture zone analysis, and ground water modeling results. We assume that hydraulic tests will be conducted on all proposed extraction wells. The actual number of extraction wells and locations will be determined by capture zone analysis in a manner to remediate the entire plume, and will be specified in the Remedial Design reports. We assume that long term (2 week) hydraulic tests will be conducted on

all proposed extraction wells. The data collected during these tests will be used to calibrate flow models, estimate hydraulic capture areas, and predict time to cleanup.

4. Soil vapor extraction is included as a module at any release site where: (a) this technology is appropriate to reduce risk or hazard posed by volatilization of contaminants from subsurface soil, or (b) data and modeling indicate that volatile contaminants are present in the subsurface in concentrations sufficient to potentially contaminate, or continue to contaminate, ground water in concentrations above background or detection limits.
5. The objectives of soil vapor extraction are to: (a) reduce contaminant concentration and mass, (b) reduce risk or hazard posed by potential exposure, and/or (c) protect beneficial uses of ground water.
6. For cost estimating purposes, ground water extraction is assumed to operate for 30 years, regardless of site-specific considerations. Soil vapor extraction is assumed to operate for 10 years.
7. Dual-phase and thermally-enhanced soil vapor extraction are retained as optional technologies, but are not formally included as modules. Offsite disposal or regeneration is the default disposition for spent vapor-phase GAC; onsite regeneration is retained as an option.
8. The default *ex situ* treatment technology for VOCs in ground water is aqueous-phase GAC, depending on flow rate and influent concentration. Aqueous-phase GAC is also the default treatment technology for High Explosive (HE) compounds and perchlorate (based on recent tests). Because more testing is required to demonstrate GAC as effective for perchlorate in all situations, the use of fixed-film bioreactors will be retained as an optional technology, where necessary to meet discharge requirements. Fixed-film bioreactors are the default treatment for nitrate, and ion exchange is the default treatment for uranium-238. Electro-osmosis is retained as an optional technology to enhance ground water extraction, but is not formally included in the modules. Innovative biological and chemical treatment are retained as optional *ex situ* treatment technologies for all compounds, and will be evaluated at a later stage in the remedial design process. Offsite disposal or regeneration is the default disposition for spent aqueous-phase GAC, ion exchange resin, and ion exchange brine; onsite regeneration is retained as an option. Ion-exchange brine and resin containing uranium-238 will be disposed offsite as low-level radioactive waste.
9. Ground water treatment units (GWTUs) are specified where electrical power is available. Solar Water Treatment (SWAT) units are specified for remote areas when no electrical power is available.
10. Ground water extraction using a siphon is considered where feasible (the Building 832 Canyon).
11. All treated ground water will be discharged to the ground surface in compliance with Substantive Requirements or a National Pollution Discharge Elimination System (NPDES) permit. The exceptions are: (1) the Building 834 ground water treatment system, where the use of existing misting towers is retained, and (2) modules for

extracting ground water contaminated with VOCs or uranium-238 in the Building 850 and Pits 3 & 5 areas, where tritium may also be present in extracted ground water. As there is currently no viable technology available for the treatment of tritiated ground water, the treated water containing only tritium would be re-injected. Safety precautions would need to be implemented to prevent exposure to tritium during the extraction and re-injection process.

The efficacy of this remedial strategy would depend on the volume and tritium levels in the water to be re-injected, as well as the re-injection location. Modeling would need to be conducted prior to implementation of this type of remedial action to ensure that re-injection would not result in inundation of a source area and further mobilization of the tritium plume. If the modeling results indicate that the re-injection of even limited volumes of water could potentially result in further releases and/or the spread of the tritium plume, the implementability of this remedial strategy may be limited. The location of injection wells, if any, will be discussed with the regulatory agencies when the remedial design for the relevant OU is prepared.

12. All treated soil vapor will be discharged to the atmosphere in compliance with San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD) permits.

The following activities are included in ground water and/or soil vapor extraction and treatment modules:

1. Design and construct additional extraction wells, if required.
2. Convert existing monitor wells to extraction wells, if required.
3. Design the extraction wellfield.
4. Perform hydraulic and/or soil vapor extraction testing.
5. Produce a Remedial Design report.
6. Obtain required operation and discharge permits.
7. Design and construct treatment facilities and effluent discharge systems.
8. Design and construct pipelines.
9. Conduct start-up sampling and analysis.
10. Perform extraction well sampling and analysis.
11. Operate and maintain the extraction well field and treatment facility.
12. Optimize the extraction wellfield and treatment facility.
13. Perform ground water and/or soil vapor flow and contaminant transport modeling.
14. Conduct data analysis and presentation.
15. Document facility operation and compliance.
16. Dispose waste (spent GAC, ion exchange brine) offsite.

4.1.2.6. Enhanced In Situ Bioremediation

1. This technology is included as a module at the Building 834 OU where analytical data indicate that the biodegradation potential at the site is high but actual contaminant degradation rates may be limited by a lack of nutrients, carbon sources, and/or electron acceptors required by microorganisms.
2. For cost estimating purposes, enhanced *in situ* bioremediation is assumed to continue for 30 years.

The following activities are included in the enhanced in situ bioremediation module:

1. Conduct microcosm experiments to determine required supplements.
2. Perform hydraulic testing.
3. Produce a Remedial Design report.
4. Design and construct the injection well field to inject microbial supplements.
5. Produce appropriate documentation.
6. Operate and maintain the injection wellfield.
7. Conduct data analysis and presentation.
8. Perform modeling.
9. Conduct intensive monitor well sampling and analysis.
10. Optimize injection wellfield and remedial performance.

4.1.2.7. In Situ Reactive Barrier

8. *In situ* reactive barriers are included as modules at the Landfill Pit 7 Complex and Building 850 areas where site-specific conditions indicate that migration of uranium-238 in ground water may be effectively controlled by this technology.
9. For cost estimating purposes, operation of an *in situ* reactive barrier is assumed to be maintained for 30 years.

The following activities are included for in situ reactive barrier treatment modules:

1. Design and construct additional monitor wells, if required.
2. Perform ground water flow and contaminant transport modeling.
3. Conduct bench-scale and column-scale treatability testing of ground water from the barrier site to help select the reactive material and to predict chemical reactions.
4. Produce a remedial design report.
5. Design and install the reactive barrier.
6. Periodically replace and dispose of the spent reactive materials offsite in compliance with ARARs.
7. Conduct intensive monitor well sampling and analysis to verify performance.

8. Perform data analysis and representation.

4.1.2.8. Excavation of Soil and Bedrock Underlying Firing Tables and Removal of Adjacent Surface Soil

1. Excavating contaminated soil and bedrock underlying the Building 850 HE firing table, and/or removing surface soil surrounding this firing table is presented because: (a) a baseline health risk greater than 1×10^{-4} or HI greater than 1 is present, and (b) there is an actual or potential impact to ground water in concentrations exceeding background. We estimate that the volume of material excavated is sufficient to address these concerns.
2. For cost estimating purposes, we assume that all excavated material would be classified as low-level radioactive waste with the exception of PCB-contaminated surface soil from Building 850, which would be classified as mixed low-level radioactive and hazardous waste.
3. Firing table excavations would be 10 feet deep or less, based on contaminant concentration profiles developed as a result of previous characterization at the firing tables.
4. Surface soil excavations would remove approximately 0.5 feet of material.

The following activities are included in excavation and/or surface soil removal modules:

1. Produce a Remedial Design report.
2. Mobilize and set-up at the excavation site.
3. Implement a worker health and safety program.
4. Excavate or remove contaminated material.
5. Conduct excavation limit, waste characterization, and confirmation sampling.
6. Load the waste for shipment.
7. Transport the waste and dispose the waste appropriately.
8. Backfill, compact, and restore the site.
9. Demobilize.

4.1.2.9. Landfill Waste Characterization, with Contingent Monitoring, Capping, or Excavation

4.1.2.9.1. Decision process for landfill pit characterization with contingent monitoring, capping, or excavation. Five landfill pits at Site 300 are considered for possible excavation or capping (Pits, 2, 3, 5, 8, and 9). Firing table debris was placed in these unlined landfills in the 1960s to the 1980s and covered with non-engineered, native soil. This waste consists of gravel, wood, plastic sheeting, wiring, concrete blocks, and other material associated with tests of high explosive devices at the firing tables. The waste is potentially contaminated with tritium, uranium-238, PCBs, and metals. Few analytical data are available for the pit contents. Contaminants from landfill Pits 3 and 5 are known to have impacted ground water. There is no evidence of COC release from landfill Pits 2, 8, and 9, but these pits generally received the same

type of waste as Pits 3 and 5, and the potential for future releases must be considered. The volumes of the all landfills were calculated from engineering drawings, employee interviews, aerial photographs, and direct investigation. The calculated volumes are considered to be the upper bound of the possible amount of waste placed in the pits.

A strategy for addressing actual or potential releases of contaminants from these landfills is shown on Figure 4-1. The process begins with detailed characterization of the contents of the landfills, followed by modeling to estimate potential impacts to ground water, and risk assessment to evaluate potential impacts to human health and the environment. The results of these activities will be used to support remedial action decisions. Individual elements of the process and decision criteria are described in the following sections. Numerous decision points for regulatory approval are included throughout the process. If the decision on which remedial action to perform occurs after the Interim ROD, a ROD amendment will be prepared.

4.1.2.9.1.1. Characterization workplans. *Workplans are classified as primary documents in the Site 300 Federal Facility Agreement (FFA). The workplans will describe the:*

1. Sample number, location, depth of samples, and collection method,
2. Analyses to be performed,
3. Risk assessment procedure, and
4. Description of the methodology to be used to estimate ground water impacts.

4.1.2.9.1.2. Focused Remedial Investigation report. After all characterization data for a landfill have been collected, analyzed, and evaluated, a Focused Remedial Investigation report will be produced. This report will contain:

1. Descriptions of sample collection,
2. Analytical results,
3. Results of the risk assessment, and
4. Results of modeling.

4.1.2.9.1.3. Forced Feasibility Studies. Following acceptance of each Focused Remedial Investigation report by the regulatory agencies, Focused Feasibility Study reports will be produced. Data from each landfill will be compared to very specific evaluation criteria to help determine the appropriate remedial action to be implemented. In particular, the following specific questions will be considered in the Focused Feasibility Study documents:

1. What are the risks or hazards to human health or the environment posed by the waste?
2. What are the nature, concentration, and distribution of contaminants in the waste?
3. What is the potential for precipitation to infiltrate downward through the waste and mobilize contaminants?
4. What is the potential for ground water to rise into the landfills and inundate the waste, causing mobilization of contaminants?
5. What is the actual or potential (modeled) impact to ground water posed by the waste?

6. What transport mechanisms are present that may cause contaminants to be released from the waste? What is the relative importance of each mechanism?
7. Which remedial actions would best address the concerns above-listed concerns?

4.1.2.9.1.4. Potential remedial actions. DOE has preliminarily identified five possible remedial approaches to address actual or potential releases of contaminants from the landfills:

1. Monitoring only.
2. Capping.
3. Partial excavation with capping.
4. Partial excavation without capping.
5. Total excavation.

The general decision criteria that will be applied in the Analysis of Alternatives documents for each approach are described below:

Monitoring only

1. No unacceptable risk, hazard, or actual or potential impacts to ground water from the waste are identified.

Capping

1. Unacceptable risk, hazard, or actual or impact to ground water is identified which could be mitigated by capping the landfill, and
2. Direct infiltration of precipitation into the waste is significant enough to cause leaching of contaminants from the waste which could be greatly reduced by constructing a cap over the waste, and
3. No contaminant release is anticipated due to inundation of waste from rises in ground water, and
4. No discrete areas of high contaminant concentrations in the waste are identified.

Partial excavation with capping

1. Unacceptable risk, hazard, or actual or potential impact to ground water are identified which could be mitigated by partial excavation of the waste and constructing a cap over the remaining waste, and
2. Direct infiltration of precipitation into the waste is significant enough to cause leaching of contaminants from the waste which could be greatly reduced by constructing a cap over the remaining, unexcavated waste, and
3. Contaminant release is possible due to inundation of waste from rises in ground water, and
4. Discrete areas of high contaminant concentrations in the waste are identified.

Partial excavation without capping

1. Unacceptable risk, hazard, or actual or potential impact to ground water is identified which could be mitigated by partial excavation of the waste, and

2. Direct infiltration of precipitation into the waste is not significant enough to cause leaching of contaminants from the waste, and
3. Contaminant release is possible due to inundation of waste from rises in ground water, and
4. Discrete areas of high contaminant concentrations in the waste are identified.

Total excavation

1. Unacceptable risk, hazard, or actual or potential impact to ground water are identified which can only be mitigated by total excavation of the waste, and
2. Contaminant release is possible due to inundation of waste from rises in ground water, and
3. No discrete areas of high contaminant concentration in the waste are identified.

4.1.2.9.1.5. Remedial Design documents. Following selection of the remedial actions, Remedial Design documents will be produced for each landfill pit or combination of pits. Design documents are classified as primary documents in the Site 300 FFA.

4.1.2.9.1.6. Closure/Post Closure plans. Following the implementation of the selected remedial action, the appropriate closure and post-closure documents will be submitted. These include the quality control and assurance monitoring requirements, maintenance program, and contingency plan documents. Closure and post-closure documents are generally classified as primary documents in the Site 300 FFA.

4.1.2.9.1.7. Decision document modifications. Many of the characterization, evaluation, design, and closure documents will likely be produced post-ROD. Depending on the content and scope of the ROD, Explanations of Significant Difference documents or a ROD amendment may be required.

4.1.2.9.2. Landfill waste characterization. Characterization will be conducted using a phased approach. Initially, soil borings would be drilled to delineate areas of high contaminant concentrations, followed by test pits and more intensive sampling, if required. The following activities are included in landfill characterization modules:

1. Develop a sampling and analysis workplan.
2. Implement a worker health and safety plan.
3. Mobilize for field activities.
4. Use a hollow-stem auger or direct-push sampling technique to collect samples of the buried landfill materials and adjacent native soil.
5. Use a backhoe to excavate test pits and collect samples.
6. Analyze the samples.
7. Demobilize.
8. Manage, analyze, and present data.

4.1.2.9.3. Landfill monitoring. The following activities are included in landfill monitoring

modules:

1. Install additional monitor wells.
2. Measure ground water levels.
3. Perform ground water sampling and analysis.
4. Maintain monitor wells.
5. Inspect surface conditions of waste sites, and if potential disruption is visible, present plans for protecting the site.
6. Manage, analyze, and present data.

4.1.2.9.4. Landfill capping.

1. We assume that capping of Landfill Pits 2, 8, and 9 would be conducted as CERCLA actions. This allows flexibility in the format of closure plans (i.e., use of Title I/II design as a Closure Plan as was done for Landfill Pit 6 in place of generating a full Closure/Post-Closure Plan as was done for the Building 829 High Explosive Burn Pit closure).
2. Capping may not be appropriate for Landfill Pits 3 and 5 because studies conducted to date indicate that ground water enters these pits from the sides and bottoms.
3. All cost estimates are based on review of actual costs incurred during construction of the Landfill Pit 6 and/or the Building 829 HE Burn Pit caps and associated surface drainage.
4. Title I/II design costs are assumed to be the same as those incurred for design of the Building 829 HE Burn Pit cap. This represents significant cost savings from design of the Landfill Pit 6 cap because much of the original design of Landfill Pit 6 was used as a template for the Building 829 HE Burn Pit cap. We assume that similar templates would be used for design of caps for Pits 2, 8, and 9 and that these documents can be used as the Closure Plans.
5. We also assume that the Title I/II design will serve as the Closure Plan and that a separate document, the Post-Closure Plan, will be prepared.
6. Costs for the Post-Closure Plan are based on costs incurred for Landfill Pit 6.
7. Cap construction costs are estimated to be proportional to the Landfill Pit 6 and Building 829 HE Burn Pit caps, based on surface area.
8. We assume that the source of all natural materials used for the pit cap layers (subgrade, topsoil, etc.) will be a borrow source located adjacent or in close proximity to the pits. Estimated costs do not include transporting these types of materials from an off-site source.
9. Construction Quality Assurance (CQA) cost is assumed to be proportional to cap surface area.
10. LLNL Plant Engineering construction management is assumed to be equal to CQA costs based on experience with Landfill Pit 6 and the Building 829 HE Burn Pit.

11. We assume that no significant mitigation efforts will be identified on ecological and archaeological surveys.
12. Estimated costs do not include (1) demolition, associated hazardous materials characterization, and disposal of any existing structures, (2) re-routing of existing roads or installation of new access roads, (3) geotechnical studies and any associated mitigating measures for geologic hazards such as landslides or active faults, (4) installing a pore-water monitoring system (such as lysimeters) or a leachate collection system, or (5) post-closure ground water monitoring and associated reporting.
13. For cost estimating purposes, annual inspections and maintenance are assumed to be performed for 30 years.

The following activities are included in landfill capping modules:

1. Prepare Title I/II designs and specifications.
2. Prepare a Post-Closure Plan.
3. Construct a multi-layer cap and associated surface water drainage diversion structures.
4. Perform construction quality assurance in conjunction with the cap construction.
5. Perform annual cap inspection and maintenance.

4.1.2.9.5. Landfill excavation. For cost estimating purposes, we assume that total excavation of the landfills is performed. However, based on the results of waste characterization, only partial excavation may be needed. Costs to conduct partial excavation can be estimated using the cost tables presented in Appendix D (Table D-3.37). These tables include the information required to calculate excavation and disposal costs on a volumetric basis. The following activities are included in landfill excavation modules:

1. Produce a Remedial Design report.
2. Mobilize and set-up at the excavation site.
3. Implement a worker health and safety program.
4. Excavate or remove contaminated landfill debris.
5. Conduct excavation limit, waste characterization, and confirmation sampling.
6. Load the waste for shipment.
7. Transport and dispose the waste appropriately.
8. Backfill, compact, and restore the site.
9. Demobilize.

4.1.2.10. Disposal of Excavated Material

As discussed in Chapter 3 (Section 3.2.7) and Appendix C (Section C-2.7), two options are available for the disposition of excavated soil, bedrock and/or waste.

For costing purposes, the DOE assumes all excavated soil, bedrock, and waste would be classified as mixed or low-level radioactive waste.

The disposal options retained for consideration include:

1. Transportation to a permitted off-site facility for treatment, destruction, and/or disposal.
2. Placement of excavated waste in an on-site engineered containment unit either at the location of an existing landfill or outside the areas of existing contamination within a Corrective Action Management Unit (CAMU).

Figure 4-1 presents these disposal options and shows how they fit into the remedial action selection process. The primary decision criteria that will be used to select a disposal option for excavated material include: (1) the time, resources, and cost necessary to implement the disposal option, (2) engineering feasibility, (3) regulatory agency approval, and (4) public acceptance considerations.

Factors that could affect the selection of a waste disposal option include (1) waste classification, (2) the volume of excavated material, and (3) siting and approval process considerations for on-site disposal. Section C-2.7 of Appendix C provides a more detailed discussion of these factors.

For the costing of off-site disposal, DOE assumes that all excavated soil, bedrock, and waste would be transported to the Envirocare treatment/ disposal facility in Utah or a similar facility. The costs presented for this option assume total excavation of the waste contained in the landfill pits would occur and require transportation and disposal. Costs for partial excavation and disposal of waste are not included in the modules but are presented in Appendix D. These costs are based on an estimate of cost per cubic yard of waste.

Costing of on-site containment includes the assumption total excavation of the waste contained in the landfill pits would occur and the waste would be placed in an on-site engineered containment unit located in a clean area outside areas of existing contamination. Costs for waste disposal in an on-site containment unit are not included in the modules but are presented in Appendix D. These costs include the siting, site preparation, design, construction, waste transport and placement, and monitoring and maintenance of the containment unit. Associated documentation and the approval process necessary to implement on-site containment and any associated with pre-treatment (which may be required) are uncertain at this time, and therefore were not costed. DOE also assumes that there are no significant obstacles presented in the siting, approval, and/or funding process that would impact the ability to implement on-site containment.

4.1.2.11. Cost Estimation

1. Costs for Site-wide regulatory compliance and management are not included in the modules. We assume that periodic reports to the regulatory agencies will be required for all OUs regardless of the remedy selected. These costs are assumed to be comparable for each OU and are not included.
2. The labor cost of individual modules is assumed to be incurred at or below the LLNL Task Leader level.
3. Appendix D-1 provides the costs for each module of each OU other than No Further Action. The work associated with each module is organized into a series of activities. The cost given for each activity is based on the information provided in Section 4.2 of

this report. The costs are organized into Direct Capital Costs, Indirect Capital Costs, and Present Worth Annual Operation and Maintenance (O&M) Costs.

4. All costing was done following the guidance of EPA's "Remedial Action Costing Procedures Manual", Report No. EPA/600/8-87/049, dated October 1987.
5. The activities are based on the Work Breakdown Structure developed for budget estimation purposes for LLNL's Environmental Restoration Division.
6. We developed a cost for each activity. The basis of the unit cost is a series of assumptions regarding the resources that will be needed to complete the activity and the quantity of those resources.
7. The quantity of each resource used for the unit costs is based on contemporaneous experience for ongoing activities at LLNL. For the case of excavation and disposal of low level and mixed wastes, recent experience at the Laboratory for Energy-Related Health Research located in Davis, CA is used.
8. We based the unit cost of each resource on a table developed by ERD for budget estimation purposes. For personnel, the cost is the average salary rate for all persons in a category, such as all scientists and engineers. For almost all other resources the unit cost is based on a current contract, such as the hourly cost for a mud rotary drilling rig used to install monitoring wells. All LLNL overhead rates and taxes are included in the unit costs.
9. The unit cost for each activity is provided in Appendix D-2 and the basis for each activity's unit cost is provided in Appendix D-3.
10. The base year for all cost estimates is fiscal year 1999.
11. Present worth cost estimates are calculated using a discount rate of 5%. The period of performance is assumed to be 30 years for all ongoing activities except for Operation and Maintenance of soil vapor extraction and treatment systems where it is assumed to be 10 years.

4.2. Descriptions of Remediation Modules

This section describes the remediation modules that have passed the screening. Each module description includes objectives, scope, and costs for each area. The scope generally includes site-specific conceptual design elements used for cost estimation, which supplement the information presented in Section 4.1. Table 4-1 summarizes the remediation modules for all areas. Table 4-2 describes how all COCs are addressed by the remediation modules. The detailed analysis of modules in Chapter 5 includes site-specific considerations relating to effectiveness and implementation. In Chapter 6, the modules are assembled into remedial alternatives that are evaluated and compared in Chapter 7.

4.2.1. Remediation Modules: Building 834 OU

4.2.1.1. Building 834 OU—Module A: No further action.

Objectives:

1. None. Included for comparison.

Scope:

1. No further investigation, sampling, or analyses would be performed.
2. There are no COCs identified for a no further action module in this area.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$0

Total Present Worth Cost: \$0

4.2.1.2. Building 834 OU—Module B: Monitoring.**Objective:**

1. Periodically collect and analyze ground water samples and perform water level measurements. This module does not include these activities when performed to support the operation and optimization of remedial actions, e.g., the scope and cost of sampling extraction wells.

Scope:

1. Sample and analyze ground water and measure water levels at 47 wells.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$2,257,000

Total Present Worth Cost: \$2,257,000

4.2.1.3. Building 834 OU—Module C: Risk and hazard management.**Objectives:**

1. Manage human health risk resulting from potential inhalation of VOC-contaminated vapor volatilizing from the subsurface to outdoor air near Building 834D. The baseline estimated risk from this pathway is 4.5×10^{-5} , with a HI of 3.2.
2. Manage human health risk resulting from potential inhalation of VOC-contaminated vapor volatilizing from the subsurface to indoor air within Building 834D. The baseline estimated risk from this pathway is 1×10^{-3} , with a HI of 36.
3. Ensure that the risks and hazards estimated in the baseline human health and ecological risk assessments are not exceeded due to changing conditions at the site, and that the remedy remains protective of human health and the environment.
4. Ensure compliance with RAOs.
5. Manage ecological hazard to the San Joaquin kit fox and other predatory fossorial species of special concern.

Scope:

1. Implement building occupancy and land use restrictions in the vicinity of Building 834D and install warning signs. If sampling of indoor air within Building 834D indicates that risks currently exceed 10^{-6} or the HI exceeds 1, institute restrictions in building use or, if building use is again anticipated, install a building ventilation system and operated it whenever the building is occupied.
2. Develop and implement a risk and hazard monitoring and assessment program:
 - Sample outdoor ambient air annually for VOCs near Building 834D;
 - Sample indoor ambient air annually for VOCs in Building 834D;
 - Conduct semi-annual wildlife surveys by biologists to evaluate the presence of the San Joaquin kit fox and other predatory fossorial vertebrate species of special concern;
 - Integrate these data into risk assessment calculations to determine any changes in risks and hazards; and
 - Review these data to evaluate compliance with RAOs.
3. Develop and implement Operational Safety Procedures for all remedial actions where risks can be foreseen.

Cost:

Capital Cost: \$18,000

Present Worth O&M Cost: \$213,000

Total Present Worth Cost: \$231,000

4.2.1.4. Building 834 OU—Module D: Ground water and soil vapor extraction and treatment of VOCs, TBOS/TKEBS, and nitrate.**Objectives:**

1. Reduce contaminant concentrations in the vadose zone and ground water, both at the source area and downgradient.
2. Reduce contaminant mass in the subsurface.
3. Restore and protect beneficial uses of ground water.
4. Reduce human health risk resulting from potential inhalation of VOC-contaminated vapor volatilizing from the subsurface to outdoor air near Building 834D. The baseline estimated risk from this pathway is 4.5×10^{-5} , with a HI of 3.2.
5. Reduce human health risk resulting from potential inhalation of VOC-contaminated vapor volatilizing from the subsurface to indoor air within Building 834D. The baseline estimated risk from this pathway is 1×10^{-3} , with a HI of 36.

Scope:

1. Simultaneously extract ground water and soil vapor from 25 extraction wells.
2. Use seventeen existing extraction wells (W-834-B2, W-834-B3, W-834-C2, W-834-D3, W-834-D4, W-834-D5, W-834-D6, W-834-D7, W-834-D8, W-834-D10, W-834-D11, W-834-D12, W-834-D13, W-834-D14, W-834-H2, W-834-J1, and W-834-J2).
3. Convert seven existing ground water monitoring wells to extraction wells (W-834-S1, W-834-S2, W-834-S3, W-834-S2A, W-834-S8, W-834-S9, and W-834-T2).
4. Install one additional extraction well.
5. Install a total of 1,400 feet of additional piping from the extraction wells to the treatment system.
6. The screened intervals in these extraction wells range from 20 to 80 feet bgs. All extraction wells would be completed in a shallow perched water-bearing zone (Tps gravel) of low estimated permeability.
7. Perform eight hydraulic tests and four soil vapor extraction tests to evaluate sustainable ground water flow rates, hydraulic capture zones, and soil vapor extraction rates. The Tps gravel is heterogeneous and exhibits low hydraulic conductivity which will limit the effectiveness of ground water extraction in the downgradient area. Seasonal fluctuations and long-term hydrologic trends will influence ground water levels and sustained yields in the downgradient ground water extraction wells.
8. The estimated flow rate for ground water is 0.1 to 2 gpm per well, with a total flow rate to the treatment system of about 1 gpm.
9. Estimated maximum contaminant concentrations in extracted ground water are TCE at 72,000 µg/L and nitrate (as NO₃) at 200 mg/L. Based on a weighted average from all extraction wells, the estimated concentrations in treatment system influent are 40,000 to 50,000 µg/L TCE, and 100 mg/L nitrate.
10. The estimated soil vapor flow rate is about 1.0 scfm per well, with a total flow rate of about 25 to 30 scfm. The design applied vacuum is 5 to 10 inches of Hg with an estimated radius of influence of 20 to 30 feet based on a permeability of 10⁻⁹ cm².
11. The estimated maximum TCE concentration in extracted soil vapor is 20 to 30 ppm_{v/v}. Based on a weighted average from all extraction wells, the estimated initial TCE vapor concentration in treatment system influent is 10 to 20 ppm_{v/v}.
12. Treat all extracted ground water and soil vapor using the existing system. Ground water will be treated using an air sparging unit with aqueous-phase GAC polish, and phytoremediation will be added. Treat offgas using vapor-phase GAC. An oil-water gravity separator is used to separate TBOS/TKEBS from ground water prior to entering the air sparging system.
13. Treat all extracted soil vapor using vapor-phase GAC.
14. Discharge all treated water using the existing misting system.

15. Dispose spent GAC offsite.
16. The locations of the components of this remediation module are shown conceptually on Figure 4-2.

Cost:

Capital Cost: \$805,000 (capital costs for the existing system are not included)

Present Worth O&M Cost: \$8,802,000

Total Present Worth Cost: \$9,607,000

4.2.1.5. Building 834 OU—Module E: Enhanced in situ bioremediation of VOCs.**Objectives:**

1. Reduce contaminant concentrations in ground water.
2. Reduce the mass of contaminants in ground water.
3. Restore and protect beneficial uses of ground water.

Scope:

1. A total of 12 injection wells would be located in the downgradient area south of Building 834.
2. Convert eight existing monitor wells to injection wells.
3. Install four additional injection wells. The average depth of the injection wells would be approximately 70 feet.
4. Dissolve chemical amendments (e.g., methanol) in clean water and periodically inject into the aquifer.
5. Ten nearby monitor wells would be intensively sampled to determine the effectiveness of nutrient addition.
6. Before reductive dehalogenation of TCE can occur, indigenous microorganisms need to use up available dissolved oxygen and nitrate. The required ratio of nutrient to electron acceptors (sum of TCE, nitrate, and dissolved oxygen) is estimated to be 10:1.
7. The locations of the components of this remediation module are shown conceptually on Figure 4-2.

Cost:

Capital Cost: \$147,000

Present Worth O&M Cost: \$2,262,000

Total Present Worth Cost: \$2,409,000

4.2.2. Remediation Modules: Landfill Pit 6 OU

4.2.2.1. Landfill Pit 6 OU—Module A: No further action.

Objectives:

1. None. Included for comparison.

Scope:

1. No further investigation, sampling, or analyses would be performed.
2. There are no COCs identified for a no further action module in this area.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$0

Total Present Worth Cost: \$0

4.2.2.2. Landfill Pit 6 OU—Module B: Monitoring.

Objectives:

1. Periodically collect and analyze ground and surface water samples and perform water level measurements. This module does not include these activities when performed to support the operation and optimization of remedial actions, e.g., the scope and cost of sampling extraction wells.

Scope:

1. Sample and analyze ground water and measure water levels at 30 wells.
2. Sample and analyze surface water from two springs and from the pond at the ranger station.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$1,692,000

Total Present Worth Cost: \$1,692,000

4.2.2.3. Landfill Pit 6 OU—Module C: Risk and hazard management.

Objectives:

1. Manage human health risk resulting from potential inhalation of VOC-contaminated vapor volatilizing from surface water to outdoor air. The baseline estimated risk from this pathway in the vicinity of Spring 7 is 4×10^{-5} , with a HI of 1.5. An estimated baseline risk from inhalation at the SVRA residence pond was calculated as 3×10^{-6} , with a HI of less than 1. This risk was projected on predicted migration of VOCs to well CARNRW2, which has, in fact, never detected any VOCs. Because of the observed

natural attenuation of the VOCs in wells upgradient of the SVRA residence pond, the projected risk is no longer expected to exceed 10^{-6} .

2. Manage human health risk resulting from potential inhalation of VOC-contaminated vapor volatilizing from the subsurface to outdoor air near Landfill Pit 6. The baseline estimated risk from this pathway is 5×10^{-6} , with a HI of less than 1.
3. Ensure that the risks and hazards estimated in the baseline human health and ecological risk assessments are not exceeded due to changing conditions at the site, and that the remedy remains protective of human health and the environment.
4. Ensure compliance with RAOs.
5. Manage ecological hazard to San Joaquin kit fox and other predatory fossorial vertebrate species of special concern.

Scope:

1. Implement building occupancy and land use restrictions in the vicinity of Spring 7 and Landfill Pit 6 and install warning signs.
2. Develop and implement a risk and hazard monitoring and assessment program:
 - Inspect Spring 7 in conjunction with quarterly ground water monitoring of Landfill Pit 6 to determine if the spring is flowing. Ambient air sampling would only be conducted if water is flowing;
 - Sample outdoor ambient air annually for VOCs near Landfill Pit 6;
 - Conduct semi-annual wildlife surveys by biologists to evaluate the presence of the San Joaquin kit fox and other predatory fossorial vertebrate species of special concern;
 - Integrate these data into risk assessment calculations to determine any changes in risks and hazards; and
 - Review these data to evaluate compliance with RAOs.
 - Develop and implement Operational Safety Procedures for all remedial actions where risks can be foreseen.

Cost:

Capital Cost: \$18,000

Present Worth O&M Cost: \$191,000

Total Present Worth Cost: \$209,000

4.2.2.4. Landfill Pit 6 OU—Module D: Monitored natural attenuation of VOCs and tritium in ground water.

Objectives:

1. To formally implement a monitored natural attenuation remedy for contaminants of concern in ground water that will:

- a) Reduce contaminant concentrations in the ground water.
- b) Reduce contaminant mass in the ground water.
- c) Control and protect beneficial uses of ground water.

Scope:

1. Sample and analyze ground water and measure water levels at 30 wells.
2. Sample and analyze surface water from three springs and from the pond at the ranger station.
3. Install two new monitor wells east of Landfill Pit 6. Both will be approximately 150 feet deep.
4. Model tritium fate and transport.
5. Monitor perchlorate and nitrate to understand their sources, extent, and concentration trends.
6. Develop contingency criteria for determining for whether a more active remediation is necessary to address any COCs.

Cost:

Capital Cost: \$109,000

Present Worth O&M Cost: \$367,000 (see Module B for monitoring costs)

Total Present Worth Cost: \$476,000

4.2.2.5. Landfill Pit 6 OU—Module E: Ground water extraction and treatment of VOCs and perchlorate.**Objectives:**

1. Reduce contaminant concentrations in ground water.
2. Reduce contaminant mass in ground water.
3. Restore and protect beneficial uses of ground water.
4. Reduce human health hazard resulting from potential inhalation of VOC-contaminated vapor volatilizing from surface water to outdoor air. In the vicinity of Spring 7, the estimated HI hazard from this pathway is 1.5.

Scope:

1. Extract ground water from a total of five wells located east-southeast of Landfill Pit 6.
2. Convert four existing monitor wells to extraction wells (EP6-09, K6-16, K6-19, and K6-17).
3. Install one new extraction well.

4. The screened intervals in the extraction wells would be between 40 and 60 feet bgs. The extraction wells would be completed in alluvium of moderate estimated hydraulic conductivity and/or bedrock of low estimated hydraulic conductivity.
5. Perform four hydraulic tests to determine sustainable flow rates.
6. A total of 660 feet of piping from the extraction wells to the treatment system would be required.
7. The estimated ground water extraction rate is 0.5 to 1.0 gpm per well, with a total flow rate of 2 to 4 gpm.
8. The maximum estimated contaminant concentration in the extraction wells is 16 µg/L TCE and 32 µg/L perchlorate. Based on a weighted average from all extraction wells, the estimated concentration in treatment system influent would be 5 to 10 µg/L TCE and 30 µg/L perchlorate.
9. Treat ground water using one SWAT (Pit6-TF1) using aqueous-phase GAC and, if necessary to meet discharge requirements, a fixed-film bioreactor.
10. The locations of the components of this remediation module are shown conceptually on Figure 4-3.

Cost:

Capital Cost: \$515,000

Present Worth O&M Cost: \$3,523,000

Total Present Worth Cost: \$4,038,000

4.2.3. Remediation Modules: HE Process Area OU**4.2.3.1. HE Process Area OU—Module A: No further action.****Objectives:**

1. None. Included for comparison.

Scope:

1. No further investigation, sampling, or analyses would be performed.
2. The following COCs are identified for consideration in a no further action module:
 - a) HE compounds in surface soil and subsurface bedrock, and VOCs in bedrock beneath the HE rinsewater lagoons. These contaminants are present in extremely low concentrations. No risk or hazard has been identified. No technology to remediate such low concentrations of these compounds from deep bedrock has been identified. The HE lagoons were excavated and closed in 1985-1989. HE compounds in ground water remain COCs.
 - b) HE compounds beneath the HE Burn Pits and the VOCs beneath the former Drying Shed area. These contaminants are present in extremely low concentrations. No risk or hazard has been identified. No technology to remediate such low concentrations of

these compounds from deep bedrock has been identified. VOCs in ground water beneath the former Drying Shed area remain COCs.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$0

Total Present Worth Cost: \$0

4.2.3.2. HE Process Area OU—Module B: Monitoring.**Objectives:**

1. Periodically collect and analyze ground and surface water samples and perform water level measurements. This module does not include these activities when performed to support the operation and optimization of remedial actions, e.g., the scope and cost of sampling extraction wells.

Scope:

1. Sample and analyze ground water and measure water levels at 70 wells.
2. Sample and analyze surface water from two springs.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$3,297,000

Total Present Worth Cost: \$3,297,000

4.2.3.3. HE Process Area OU—Module C: Risk and hazard management.**Objectives:**

1. Manage human health risk resulting from potential inhalation of VOC-contaminated vapor volatilizing from the subsurface to outdoor air in the vicinity of Building 815. The baseline estimated risk from this pathway was 1.4×10^{-6} , with a HI of less than 1.
2. Manage human health risk resulting from potential inhalation of contaminated vapor volatilizing from surface water to outdoor air at Spring 5. The baseline estimated risk from this pathway is 1×10^{-5} , with a HI of less than 1.
3. Ensure that the risks and hazards estimated in the baseline human health and ecological risk assessments are not exceeded due to changing conditions at the site, and that the remedy remains protective of human health and the environment.
4. Ensure compliance with RAOs.

Scope:

1. Implement building occupancy and land use restrictions in the vicinity of Building 815 and Spring 5 and install warning signs.

2. Develop and implement a risk and hazard monitoring and assessment program:
 - Sample outdoor ambient air annually for VOCs near Building 815;
 - Sample outdoor ambient air annually for VOCs near Spring 5;
 - Integrate these data into risk assessment calculations to determine any changes in risks and hazards; and
 - Review these data to evaluate compliance with RAOs.
3. Develop and implement Operational Safety Procedures for all remedial actions where risks can be foreseen.

Cost:

Capital Cost: \$18,000

Present Worth O&M Cost: \$163,000

Total Present Worth Cost: \$181,000

4.2.3.4. HE Process Area OU—Module D: Ground water extraction and treatment of VOCs and nitrate at the leading edge of the Building 815 TCE plume.

Objectives:

1. Reduce contaminant concentrations in ground water.
2. Reduce contaminant mass in ground water.
3. Control contaminant migration.
4. Restore and protect beneficial uses of ground water.

Scope:

1. Two extraction wells would be located near the southern Site 300 boundary near the downgradient extent of the TCE plume. Both extraction wells would be converted monitor wells.
2. The screened intervals in the extraction wells are between 150 and 200 feet bgs. The extraction wells are completed in bedrock of 10^{-4} cm/sec estimated hydraulic conductivity.
3. No additional hydraulic tests would be required.
4. A total of 50 feet of piping from the extraction wells to the treatment systems would be required. In addition, 450 feet of piping would also be required to convey treated water to the discharge location.
5. Ground water extracted from well W-35C-04 would be treated using one SWAT unit fitted with aqueous-phase GAC (B815-TF1).
6. At the B815-TF1 SWAT, the estimated TCE concentration is 2 to 5 µg/L and the estimated flow rate is 3 gpm.

7. A second ground water monitoring well will be chosen, based on contaminant concentrations at the time the treatment unit is installed. The treatment unit (B815-TF2) would be fitted with aqueous-phase GAC, and if necessary to meet discharge requirements, a fixed-film bioreactor.
8. For costing purposes, we assume that B815-TF2 would treat a TCE concentration of 30 to 40 µg/L at a flow rate of 5 gpm.
9. Pumping from the leading edge of the TCE plume may eventually capture or influence upgradient contaminants such as RDX and perchlorate (see Module E), although extraction rates can be adjusted to minimize these effects.
10. The locations of the components of this remediation module are shown conceptually on Figure 4-4.

Cost:

Capital Cost: \$687,000

Present Worth O&M Cost: \$5,125,000

Total Present Worth Cost: \$5,812,000

4.2.3.5. HE Process Area OU—Module E: Ground water extraction and treatment of VOCs, HE compounds, nitrate, and perchlorate released from Building 815 and the high explosives rinsewater lagoons.

Objectives:

1. Reduce contaminant concentrations in ground water.
2. Reduce contaminant mass in ground water.
3. Restore and protect beneficial uses of ground water.

Scope:

1. A total of eight extraction wells would be located near Building 815 and in the area downgradient (south-southeast) of Building 815.
2. Convert seven existing monitor wells to extraction wells (W-815-01, W-815-02, W-817-01, W-817-03A, W-817-07, W-818-11, and W-818-08).
3. Install one additional extraction well.
4. The screened intervals for the extraction wells are approximately 80 to 100 feet bgs. Six of the extraction wells would be completed in bedrock (T_{nbs_2}) of 10^{-4} cm/sec estimated hydraulic conductivity, and two of the extraction wells would be completed in a shallow perched water-bearing zone (T_{ps}) of 10^{-5} cm/sec estimated hydraulic conductivity.
5. Perform eight hydraulic tests.

6. Install a total of 850 feet of piping from the extraction wells to the treatment systems. In addition, 450 feet of piping would also be required to convey treated water to the discharge locations.
7. The estimated flow rate for ground water is 1 to 2 gpm per bedrock well and 0.1 to 0.5 gpm per Tps well, for a total flow rate from all wells of 6 to 12 gpm. Sustainable yields in the Tps wells would be variable depending on time of year and amount of rainfall.
8. Treat extracted ground water using four SWAT units (B815-TF3, 4, 5, and 6), all using aqueous-phase GAC and fixed-film bioreactors.
9. At SWAT B815-TF3, the weighted average concentrations are: 80 to 90 $\mu\text{g/L}$ TCE, 8 to 10 $\mu\text{g/L}$ perchlorate, and 80 to 90 mg/L nitrate. The estimated flow rate is 2 to 3 gpm. The extraction wells to be connected to this treatment unit are W-818-08 and W-818-011.
10. At SWAT B815-TF4, the weighted average concentrations are: 120 to 130 $\mu\text{g/L}$ TCE, 20 to 30 $\mu\text{g/L}$ perchlorate, 2 to 3 $\mu\text{g/L}$ RDX, and 250 to 300 mg/L nitrate. The estimated flow rate is 2 to 3 gpm. The extraction wells to be connected to this treatment unit are W-817-03A and W-817-07.
11. At SWAT B815-TF5, the weighted average concentrations are: 250 to 300 $\mu\text{g/L}$ TCE, 5 to 10 $\mu\text{g/L}$ perchlorate, 120 to 130 $\mu\text{g/L}$ RDX, and 5 to 10 mg/L nitrate. The estimated flow rate is 2 to 3 gpm. The extraction wells to be connected to this treatment unit are W-815-01 and W-815-02.
12. At SWAT B815-TF6, the weighted average concentrations are: 1 to 5 $\mu\text{g/L}$ TCE, 10 to 20 $\mu\text{g/L}$ perchlorate, 40 to 50 $\mu\text{g/L}$ RDX, and 90 to 100 mg/L nitrate. The estimated flow rate is 2 to 3 gpm. The extraction wells to be connected to this treatment unit are W-817-01 and the new extraction well.
13. The locations of the components of this remediation module are shown conceptually on Figure 4-4.

Cost:

Capital Cost: \$1,469,000

Present Worth O&M Cost: \$12,928,000

Total Present Worth Cost: \$14,397,000

4.2.3.6. HE Process Area—Module F: Ground water extraction and treatment of VOCs, perchlorate, and nitrate released from the HE Burn Pit.**Objectives:**

- 1 Reduce contaminant concentrations in ground water.
- 2 Reduce contaminant mass in ground water.
- 3 Restore and protect beneficial uses of ground water.

Scope:

1. Extract ground water from two existing monitor wells converted to extraction wells (W-829-08 and W-828-09). Install one new extraction well.
2. The screened intervals in the extraction wells are between 75 and 100 feet bgs. The wells would be completed in alluvium or bedrock of low to moderate estimated hydraulic conductivity.
3. Perform three hydraulic tests to determine sustainable flow rates.
4. Install a total of 100 feet of piping from the extraction wells to the treatment system.
5. The estimated flow rate for ground water is 0.1 to 0.5 gpm per well, with a total flow rate of 0.3 to 1.5 gpm.
6. The maximum estimated TCE concentration in the extraction wells is 310 µg/L. Based on a weighted average from all extraction wells, the estimated contaminant concentration in treatment system influent is 200 to 300 µg/L TCE, 15 µg/L perchlorate, and 100 mg/L nitrate.
7. Treat ground water using aqueous-phase GAC and a fixed-film bioreactor contained in one SWAT unit (HEBP-TF1).
8. The locations of the components of this remediation module are shown conceptually on Figure 4-5.

Cost:

Capital Cost: \$461,000

Present Worth O&M Cost: \$3,473,000

Total Present Worth Cost: \$3,934,000

4.2.4. Remediation Modules: Landfill Pit 7 Complex**4.2.4.1. Landfill Pit 7 Complex—Module A: No further action.****Objectives:**

1. None. Included for comparison.

Scope:

1. No further investigation, sampling, or analyses would be performed.
2. The following COCs are identified for consideration in a no further action module:

Tritium and uranium-238 in surface soil outside of Landfill Pits 3, 5, and 7 have been detected only at background activities (maximum uranium-238, 1.0 pCi/g; maximum tritium, 310 pCi/L_{sm}). No risk or hazard has been identified. Tritium and uranium-238 in the landfill pits and in ground water remain COCs.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$0

Total Present Worth Cost: \$0

4.2.4.2. Landfill Pit 7 Complex—Module B: Monitoring.

Objectives:

1. Periodically collect and analyze ground water samples and perform water level measurements. This module does not include these activities when performed to support the operation and optimization of remedial actions, e.g., the scope and cost of sampling extraction wells.

Scope:

1. Sample and analyze ground water and measure water levels at 45 wells.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$2,173,000

Total Present Worth Cost: \$2,173,000

4.2.4.3. Landfill Pit 7 Complex—Module C: Risk and hazard management.

Objectives:

1. Manage human health risk resulting from potential inhalation of tritium-contaminated vapor volatilizing from the subsurface to outdoor air near Landfill Pit 3. The baseline estimated risk from this pathway is 4×10^{-6} .
2. Ensure that the risks and hazards estimated in the baseline human health and ecological risk assessments are not exceeded due to changing conditions at the site, and that the remedy remains protective of human health and the environment.
3. Ensure compliance with RAOs.
4. Manage ecological hazard to San Joaquin kit fox and other fossorial vertebrate species of special concern.

Scope:

1. Implement building occupancy and land use restrictions in the vicinity of Landfill Pit 3 and install warning signs.
2. Develop and implement a risk and hazard monitoring and assessment program:
 - Sample outdoor ambient air annually for tritium near Landfill Pit 3;
 - Integrate these data into risk assessment calculations to determine any changes in risks and hazards; and
 - Review these data to evaluate compliance with RAOs.

- 3 Develop and implement Operational Safety Procedures for all remedial actions where risks can be foreseen.

Cost:

Capital Cost: \$18,000

Present Worth O&M Cost: \$212,000

Total Present Worth Cost: \$230,000

4.2.4.4. Landfill Pit 7 Complex—Module D: Monitored natural attenuation of tritium in ground water.**Objectives:**

1. To formally implement a monitored natural attenuation remedy for tritium in ground water.

Scope:

1. Sample and analyze ground water and measure water levels at 47 wells.
2. Evaluate monitoring data, compare to expectations, and report results. These activities are included in the cost estimates.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$283,000 (see Module B for monitoring costs)

Total Present Worth Cost: \$283,000

4.2.4.5. Landfill Pit 7 Complex—Module E: Ground water extraction and treatment of VOCs.**Objectives:**

1. Reduce contaminant concentrations in ground water.
2. Reduce contaminant mass in ground water.
3. Restore and protect beneficial uses of ground water.

Scope:

1. Extract ground water from four existing monitor wells converted to extraction wells (NC7-51, K7-03, and NC7-67).
2. The screened intervals in the extraction wells are between 15 and 60 feet bgs. The wells are completed in alluvium or bedrock of low to moderate estimated hydraulic conductivity.
3. Perform three hydraulic tests to determine sustainable flow rates.
4. Install a total of 250 feet of piping from the extraction wells to the treatment system.
5. The estimated flow rate for ground water is 0.1 to 0.5 gpm per well, with a total flow rate of 0.3 to 1.5 gpm.

6. The maximum estimated TCE concentration in extracted ground water is 5 µg/L. Based on a weighted average from all extraction wells, the estimated TCE concentration in treatment system influent is 1 to 2 µg/L. However, tritium activity in extracted ground water may exceed 1,000,000 pCi/L, and uranium may exceed 76 pCi/L.
7. Treat ground water using aqueous-phase GAC and ion exchange contained in one SWAT unit (B850-TF1).
8. Treated water containing tritium would be reinjected using five new injection wells downgradient of Building 850.
9. Install a total of 2,200 feet of pipeline to reach the injection well.
10. The locations of the components of this remediation module are shown conceptually on Figure 4-6.

Cost:

Capital Cost: \$701,000

Present Worth O&M Cost: \$3,048,000

Total Present Worth Cost: \$3,749,000

4.2.4.6. Landfill Pit 7 Complex—Module F: Ground water extraction and treatment of uranium-238 and nitrate.**Objectives:**

1. Reduce contaminant concentrations in ground water.
2. Reduce contaminant mass in ground water.
3. Restore and protect beneficial uses of ground water.

Scope:

1. Extract ground water from eleven wells located near the center of mass of the plume of uranium-238 in ground water near Pits 3 and 5.
2. Convert six monitor wells to extraction wells (NC7-37, NC7-48, NC7-16, NC7-51, NC7-34, and NC7-40).
3. Install five additional extraction wells.
4. The screened intervals of the extraction wells would be approximately 25 to 50 feet bgs. All extraction wells would be completed in alluvium of high estimated permeability or bedrock of low to moderate estimated permeability.
5. Perform eleven hydraulic tests.
6. Install a total of 3,100 feet of piping from the extraction wells to the treatment system. Install an additional 2,000 feet of pipeline from the treatment facilities to the injection wells located downgradient of Building 850.

7. The estimated flow rate for ground water is 0.1 to 0.3 gpm per well, with a total flow rate of 1.5 to 4 gpm.
8. Based on a weighted average from all extraction wells, the estimated contaminant concentrations in treatment system influent are a 35 pCi/L uranium-238 and 130 mg/L nitrate. However, ground water from many of the extraction wells may also contain up to 1,000,000 pCi/L tritium.
9. Treat ground water extracted using a SWAT unit (B850-TF1), using ion exchange and fixed-film bioreactors.
10. Reinject treated water containing tritium using five new injection wells downgradient of Building 850. The cost of these injection wells is also included in Building 850 Module E.
11. The locations of the components of this remediation alternative are shown conceptually on Figure 4-6.

Cost:

Capital Cost: \$1,682,000

Present Worth O&M Cost: \$3,694,000

Total Present Worth Cost: \$5,376,000

4.2.4.7. Landfill Pit 7 Complex—Module G: Control migration of uranium-238 in ground water using an in situ reactive permeable barrier.**Objectives:**

- Reduce contaminant concentration and mobility in ground water.
- Reduce contaminant mass in ground water.
- Control contaminant migration by immobilizing uranium-238 in excess of background activities in ground water downgradient of Landfill Pits 3, 5, and 7.
- Restore and protect beneficial uses of ground water.

Scope:

- Install a reactive barrier downgradient of Landfill Pit 5. The barrier would be 250 feet long and 10 feet wide, excavated to a depth of 30 feet, and filled with iron filings encased in resistant netting from a depth of 10 to 30 feet bgs. The encased iron filings would be removed and replaced every 10 years to refresh the reactive materials and remove the precipitated uranium.
- The estimated concentrations of contaminants on the upgradient side of the Landfill Pit 5 barrier are 20 pCi/L total uranium, 65 mg/L nitrate, and 100,000 pCi/L tritium. The barrier would be designed to reduce the concentration of uranium-238 to levels below detection limits. The capability of a permeable reactive barrier using iron filings to reduce nitrate concentration is being investigated. Tritium would be unaffected by the barrier.

- To monitor the effectiveness of the reactive barriers, install five additional monitor wells immediately downgradient of the Landfill Pit 5 barrier.
- Conduct column and bench-scale treatability tests prior to installing the barrier to estimate the surface area, thickness, effective life, and other design components.
- Dispose the spent ion-exchange brine and resin offsite as low-level radioactive waste.
- The locations of the components of this remediation alternative are shown conceptually on Figure 4-6.

Cost:

Capital Cost: \$4,341,000 (includes reinstalling reactive components at years 10 and 20)

Present Worth O&M Cost: \$0

Total Present Worth Cost: \$4,341,000

4.2.4.8. Landfill Pit 7 Complex—Module H: Waste characterization with contingent monitoring, capping, and/or excavation of Landfill Pits 3 and 5.

Objectives:

1. Control contaminant sources.
2. Reduce contaminant mass in the subsurface.
3. Prevent continued contamination of ground water.
4. Protect beneficial uses of ground water.

Scope:**Waste Characterization for Landfill Pits 3 and 5**

1. Using a backhoe, excavate two test pits each in Landfill Pits 3 and 5. Each test pit would be benched (or shored) to achieve a uniform depth of 20 feet. Each test pit would be 50 feet long.
2. Collect fill/waste samples from 4 vertical profiles, spaced at 10 feet intervals along the length of each test pit. Collect and analyze samples at depths of 2, 5, 10, 15, and 20 feet from each of the test pits for the following analytes:
 - Tritium
 - Nitrate (as NO₃)
 - Soluble threshold limit concentration (STLC) metals (including beryllium)
 - Total threshold limit concentration (TTLC) metals (including beryllium)
 - Uranium and thorium isotopes
3. Additionally, analyze samples from a depth of 10 feet at each test pit for each of the following analytes:

- HE compounds
 - VOCs
 - CBs
4. Backfill the test pits.
 5. Auger or use a direct-push sampling rig to drill 8 boreholes within each landfill.
 6. Collect samples at depths of 2, 5, 10, 15, and 20 feet for the following analytes:
 - Tritium
 - Nitrate (as NO₃)
 - STLC metals (including beryllium)
 - TTLC metals (including beryllium)
 - Uranium and thorium isotopes
 7. Additionally, analyze samples from a depth of 10 feet for each of the following analytes:
 - HE compounds
 - VOCs
 - PCBs
 8. Backfill the auger/direct-push holes.
 9. Review the analytical data and apply the decision process described in Section 4.1.2.9.1 to determine whether capping or removal is necessary. If excavation is required, determine the volume of waste that would need to be excavated. (Note that capping is not costed below because this does appear a viable approach to prevent Pits 3 and 5 from further releases.)
 10. Revise estimates for waste classification and total volumes of waste.

Cost:

Capital Cost: \$503,000

Present Worth O&M Cost: \$0

Total Present Worth Cost: \$503,000

Excavation of Landfill Pit 3

1. Excavate contaminated firing table debris from Landfill Pit 3.
2. The estimated depth of excavation is approximately 20 feet.
3. The total estimated volume of excavated material is 26,200 yd³.
4. The maximum concentration of contamination associated with the buried debris is about 10,000,000 pCi/L (soil moisture) tritium. The maximum concentrations of other contaminants possibly present in the pit (uranium-238, metals, PCBs) are undetermined.

5. Job planning costs of about \$93,000 for all excavation/disposal at Site 300 are arbitrarily assigned to the Pit 3 excavation costs. Mob/demob costs of about \$125,000 for any excavation at Pits 3 or 5 are arbitrarily assigned to the Pit 3 excavation costs.
6. The locations of the components of this remediation module are shown conceptually on Figures 4-7 and 4-8.

Excavation of Landfill Pit 5

1. Excavate contaminated firing table debris from Landfill Pit 5.
2. The estimated depth of excavation is approximately 20 feet.
3. The total estimated volume of excavated material is 29,900 yd³.
4. The maximum concentration of contamination associated with the buried debris is about 10,000,000 pCi/L (soil moisture) tritium. The maximum concentrations of other contaminants possibly present in the pit (uranium-238, metals, PCBs) are undetermined.
5. The locations of the components of this remediation module are shown conceptually on Figures 4-7 and 4-8.

Waste Disposal

1. The estimated total volume of waste is 56,100 yd³, assumed to be low-level radioactive waste. This represents a maximum volume, and assumes that the entire contents of the landfills require excavation. If feasible, DOE will selectively remove waste determined by the characterization process to act as on-going or potential sources of ground water contamination or that present risk to human health and the environment. This could significantly reduce the volume of waste requiring disposal, and corresponding costs.
2. Maximum costs include transport to and disposal of the entire landfill contents at the Envirocare Utah facility. Actual costs would depend on waste volume excavated (see decision process, Section 4.1.2.9.1) and the disposal option chosen.

Cost:

Capital Cost: \$47,093,000

Present Worth O&M Cost: \$0

Total Present Worth Cost: \$47,093,000

Total Module Cost:

\$503,000 (waste characterization only)

\$47,596,000 (waste characterization plus total excavation)

Because of up-front siting, design, and approval requirements for an on-site consolidation unit, off-site disposal is likely to be less expensive for small amounts of waste (perhaps up to 10% of the landfill volume), whereas on-site disposal may be considerably less expensive if the characterization process determines that the entire landfill should be excavated.

4.2.5. Remediation Modules: Building 850

4.2.5.1. Building 850—Module A: No further action.

Objectives:

1. None. Included for comparison.

Scope:

1. No further investigation, sampling, or analyses would be performed.
2. There are no COCs identified for a no further action module in this area.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$0

Total Present Worth Cost: \$0

4.2.5.2. Building 850—Module B: Monitoring.

Objectives:

1. Periodically collect and analyze ground and surface water samples and perform water level measurements. This module does not include these activities when performed to support the operation and optimization of remedial actions, e.g., the scope and cost of sampling extraction wells.

Scope:

1. Sample and analyze ground water and measure water levels at 47 wells.
2. Sample and analyze surface water at one spring.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$2,294,000

Total Present Worth Cost: \$2,294,000

4.2.5.3. Building 850—Module C: Risk and hazard management.

Objectives:

1. Manage human health risk resulting from potential incidental ingestion and direct dermal contact with surface soil contaminated with PCBs, and dioxins/furans at the

Building 850 firing table. The baseline estimated risks from this pathway are 5.3×10^{-3} for PCBs and 9.5×10^{-5} for dioxins/furans.

2. Ensure that the risks and hazards estimated in the baseline human health and ecological risk assessments are not exceeded due to changing conditions at the site, and that the remedy remains protective of human health and the environment.
3. Ensure compliance with RAOs.
4. Manage ecological hazard to San Joaquin kit fox and other fossorial vertebrate species of special concern.

Scope:

1. Implement building occupancy and land use restrictions in the vicinity of the Building 850 firing table and install warning signs.
2. Develop and implement a risk and hazard monitoring and assessment program:
 - Sample surface soil annually for PCBs near the Building 850 firing table;
 - Sample surface soil annually for dioxins and furans near the Building 850 firing table;
 - Conduct semi-annual wildlife surveys by biologists to evaluate the presence of any species of special concern;
 - Integrate these data into risk assessment calculations to determine any changes in risks and hazards; and
 - Review these data to evaluate compliance with RAOs.
3. Develop and implement Operational Safety Procedures for all remedial actions where risks can be foreseen.

Cost:

Capital Cost: \$18,000

Present Worth O&M Cost: \$206,000

Total Present Worth Cost: \$224,000

4.2.5.4. Building 850—Module D: Monitored natural attenuation of tritium in ground water and surface water.

Objectives:

1. To formally implement a monitored natural attenuation remedy for tritium in ground water and surface water (Well 8 Spring).

Scope:

1. Sample and analyze ground water and measure water levels at 45 wells.
2. Sample and analyze surface water from one spring.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$283,000 (see Module B for monitoring costs)

Total Present Worth Cost: \$283,000

4.2.5.6. Building 850—Module E: Ground water extraction and treatment of uranium-238 and nitrate.**Objectives:**

1. Reduce contaminant concentrations in ground water.
2. Reduce contaminant mass in ground water.
3. Restore and protect beneficial uses of ground water.

Scope:

1. Extract ground water from four wells located near the center of mass of the uranium-238 plume in ground water near Building 850.
2. Convert four monitor wells to extraction wells (NC7-28, NC7-61, NC7-70, and NC7-11).
3. The screened intervals of the extraction wells would be approximately 25 to 50 feet bgs. All extraction wells would be completed in alluvium of high estimated permeability or bedrock of low to moderate estimated permeability.
4. Perform four hydraulic tests.
5. Install a total of 1,600 feet of piping from the extraction wells to the treatment system. Install an additional 600 feet of piping from the treatment facilities to the injection wells, located downgradient of Building 850.
6. The estimated flow rate for ground water is 0.1 to 0.3 gpm per well, with a total flow rate of 1.5 to 4 gpm.
7. Based on a weighted average from all extraction wells, the estimated contaminant concentrations in treatment system influent are 35 pCi/L uranium-238 and 130 mg/L nitrate. However, ground water from many of the extraction wells may also contain up to 2,000,000 pCi/L tritium.
8. Treat ground water extracted using a SWAT unit (B850-TF2), using ion exchange and fixed-film bioreactors.
9. Reinject treated water containing tritium using five new injection wells downgradient of Building 850. The cost of these injection wells is also included in Landfill Pit 7 Complex Module F.
10. The locations of the components of this remediation alternative are shown conceptually on Figure 4-6.

Cost:

Capital Cost: \$971,000

Present Worth O&M Cost: \$3,504,000

Total Present Worth Cost: \$4,475,000

4.2.5.7. Building 850—Module F: Control migration of uranium-238 in ground water using an in situ reactive permeable barrier.**Objectives:**

1. Reduce contaminant concentration and mobility in ground water.
2. Reduce contaminant mass in ground water.
3. Control contaminant migration by immobilizing uranium-238 in excess of background activities in ground water downgradient of Building 850.
4. Restore and protect beneficial uses of ground water.

Scope:

1. Install a reactive barrier downgradient of Building 850 in the saturated alluvial channel fill of Doall Ravine. This barrier would be 150 feet long, 10 feet wide, and 30 feet deep filled with iron filings encased in resistant netting from 20 to 30 feet below bgs.
2. The estimated concentrations of contaminants on the upgradient side of the Building 850 barrier are a 20 pCi/L total uranium, 97 mg/L nitrate, and 20,000 pCi/L tritium. The barrier would be designed to reduce the concentrations of uranium-238 to levels below detection limits. The capability of a permeable reactive barrier using iron filings to reduce nitrate concentration is being investigated. Tritium would be unaffected by the barrier.
3. To monitor the effectiveness of the reactive barriers, three additional monitor wells would be installed immediately downgradient of the Building 850 barrier.
4. Conduct column and bench-scale treatability tests prior to installing the barrier to estimate the surface area, thickness, effective life, and other design components.
5. Dispose the spent ion-exchange brine and resin offsite as low-level radioactive waste.
6. The locations of the components of this remedial alternative are shown conceptually on Figure 4-6.

Cost:

Capital Cost: \$3,376,000 (includes reinstalling reactive components at years 10 and 20)

Present Worth O&M Cost: \$0

Total Present Worth Cost: \$3,376,000

4.2.5.8. Building 850—Module G: Excavation of contaminated soil and bedrock underlying the Building 850 firing table, removal of the contaminated sandpile, and removal of contaminated soil adjacent to the firing table.

Objectives:

1. Manage human health risk resulting from potential incidental ingestion and direct dermal contact with surface soil contaminated with PCBs, and dioxins/furans at the Building 850 firing table. The baseline estimated risks from this pathway are 5.3×10^{-3} for PCBs and 9.5×10^{-5} for dioxins/furans.
2. Control contaminant sources.
3. Prevent continued contamination of ground water.
4. Protect beneficial uses of ground water.

Scope:

Excavate contaminated soil and bedrock underlying the Building 850 firing table.

1. The estimated areal extent of excavation is 6,750 ft².
2. The estimated depth of excavation is approximately 20 feet.
3. The total estimated volume of excavated material is 5,000 yd³.
4. The maximum concentrations of COCs associated with the soil and bedrock are 7,300,000 pCi/L (soil moisture) tritium, and 28.1 pCi/g uranium-238.
5. The material removed is assumed to be low-level radioactive waste, and would be disposed offsite.
6. The locations of the components of this remediation module are shown conceptually on Figures 4-7 and 4-9.

Cost:

Capital Cost: \$4,377,000

Present Worth O&M Cost: \$0

Total Present Worth Cost: \$4,377,000

Remove the contaminated sandpile at the Building 850 firing table.

1. The estimated areal extent of removal is 1,250 ft².
2. The sandpile is approximately 10 feet high.
3. The total estimated volume of material to be removed is 460 yd³.
4. The maximum concentrations of contaminants detected in the sandpile are 204,000 pCi/L (soil moisture) tritium, and 4.5 mg/L copper using the STLC method.

5. The material removed is assumed to be low-level radioactive waste, and would be disposed offsite.
6. The locations of the components of this remedial module are shown conceptually on Figures 4-7 and 4-9.

Remove surface soil adjacent to the Building 850 firing table

1. Remove the surface soil contaminated with ejecta from explosive tests at the Building 850 firing table.
2. The estimated areal extent of removal is 43,700 ft².
3. The estimated depth of removal is approximately 0.5 feet.
4. The total estimated volume of material to be removed is 800 yd³.
5. The maximum concentrations of contaminants associated with the surface soil are 25 pCi/g uranium-238, 51,200 pCi/L (soil moisture) tritium, 180 mg/kg PCBs, 4.3 pg/g dioxins, 15,000 pg/g furans, 1,000 mg/kg copper (TTLC method), 15 mg/kg beryllium (TTLC method), 43 mg/kg lead (TTLC method), and 2.4 mg/kg HMX.
6. The material removed is assumed to be mixed low-level radioactive and hazardous waste, and would be disposed offsite.
7. The locations of the components of this remediation module are shown conceptually on Figures 4-7 and 4-9.

Cost:

Capital Cost: \$1,068,000

Present Worth O&M Cost: \$0

Total Present Worth Cost: \$1,068,000

Total Module Cost:

\$1,115,000 (sandpile plus surface soil includes mob/demob costs for the area plus the cost of a Remedial Design Report)

\$5,4445,000 (sandpile plus surface soil plus subsurface soil/bedrock)

4.2.6. Remediation Modules: Landfill Pit 2

4.2.6.1. Landfill Pit 2—Module A: No further action.

Objectives:

1. None. Included for comparison.

Scope:

1. No further investigation, sampling, or analyses would be performed.
2. There are no COCs identified for a no further action module in this area.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$0

Total Present Worth Cost: \$0

4.2.6.2. Landfill Pit 2—Module B: Monitoring.**Objectives:**

1. Periodically collect and analyze ground and surface water samples and perform water level measurements. This module does not include these activities when performed to support the operation and optimization of remedial actions, e.g., the scope and cost of sampling extraction wells.

Scope:

1. Sample and analyze ground water and measure water levels at 3 wells.
2. Sample and analyze surface water at one spring.
3. Inspect landfill surface for damage that could compromise the integrity of the landfill, and if such damage is found, arrange for repair.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$515,000

Total Present Worth Cost: \$515,000

4.2.6.3. Landfill Pit 2—Module C: Waste characterization with contingent monitoring, capping, or excavation of Landfill Pit 2.**Objectives:**

1. Control contaminant sources.
2. Reduce the mass of contaminants in the subsurface.
3. Prevent potential contamination of ground water.
4. Protect beneficial uses of ground water.

Scope:**Waste Characterization of Landfill Pit 2**

1. Using a backhoe, excavate two test pits in Landfill Pit 2. Each test pit would be benched (or shored) to achieve a depth of 20 feet. Each test pit would be 50 feet long.
2. Collect fill/waste samples from 4 vertical profiles, spaced at 10 ft intervals along the length of each test pit. Collect and analyze samples at depths of 2, 5, 10, 15, and 20 feet from each of the test pits for the following analytes:
 - Tritium

- STLC metals (including beryllium)
 - TTLC metals (including beryllium)
 - Uranium and thorium isotopes
3. Additionally, analyze samples from a depth of 10 feet at each test pit for each of the following analytes:
 - HE compounds
 - PCBs
 4. Backfill the test pits.
 5. Auger or use a direct-push rig to drill 8 boreholes within each landfill.
 6. Collect samples at depths of 2, 5, 10, 15, and 20 feet for the following analytes:
 - Tritium
 - STLC metals (including beryllium)
 - TTLC metals (including beryllium)
 - Uranium and thorium isotopes
 7. Additionally, analyze samples from a depth of 10 feet for each of the following analytes:
 - HE compounds
 - PCBs
 8. Backfill the auger/direct-push holes.
 9. Review the analytical data and apply the decision process described in Section 4.1.2.9.1 to determine whether capping or removal is necessary. If excavation is required, determine the volume of waste that would need to be excavated.
 10. Revise estimates for waste classification and total volumes of waste.

Cost:

Capital Cost: \$252,000

Present Worth O&M Cost: \$0

Total Present Worth Cost: \$252,000

Capping of Landfill Pit 2

1. Design and construct a multi-layer cap and associated surface water drainage.
2. The estimated area of the cap is 90,000 ft².
3. Perform annual inspections and maintenance of the cap and drainage system.

Cost:

Capital Cost: \$1,026,000

Present Worth O&M Cost: \$154,000

Total Present Worth Cost: \$1,180,000

Excavation of Landfill Pit 2

1. Excavate contaminated firing table debris from Landfill Pit 2. This could range from a small portion to the entire landfill, depending on the quantity of material determined to cause significant risk (see decision process, Section 4.1.2.9.1).
2. The estimated depth of excavation is approximately 20 feet.
3. The total estimated volume of excavated material is 25,412 yd³.
4. No analytical data are available for contaminants that may be present in Landfill Pit 2, but tritium, uranium-238, and metals were possibly disposed in the pit.
5. The excavated material is assumed to be low-level radioactive waste, and would be disposed of as described in Section 4.1.2.1.0.
6. The locations of the components of this remediation module are shown conceptually on Figures 4-7 and 4-10.

Cost:

Capital Cost: \$21,483,000

Present Worth O&M Cost: \$0

Total Present Worth Cost: \$21,483,000

Total Module Cost:

\$252,000 (waste characterization only)

\$1,432,000 (waste characterization plus capping)

\$21,735,000 (waste characterization plus excavation with offsite disposal)

4.2.7. Remediation Modules: Building 854 OU

4.2.7.1. Building 854 OU—Module A: No further action.

Objectives:

1. None. Included for comparison.

Scope:

1. No further investigation, sampling, or analyses would be performed.
2. The following COCs are identified for consideration in a no further action module:
 - a) Metals, HMX, and tritium in surface soil have been detected in extremely low concentrations. No risk or hazard has been identified. Vadose zone modeling estimates the maximum concentration of lead to reach ground water would be 1.9 µg/L in 200,000 years, and HMX at 1.7 mg/L in 500 years.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$0

Total Present Worth Cost: \$0

4.2.7.2. Building 854 OU—Module B: Monitoring.**Objectives:**

1. Periodically collect and analyze ground and surface water samples and perform water level measurements. This module does not include these activities when performed to support the operation and optimization of remedial actions, e.g., the scope and cost of sampling extraction wells.

Scope:

1. Sample and analyze ground water and measure water levels at 14 wells.
2. Sample and analyze surface water from two springs.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$945,000

Total Present Worth Cost: \$945,000

4.2.7.3. Building 854 OU—Module C: Risk and hazard management.**Objectives:**

1. Manage human health risk resulting from potential inhalation of VOC vapor volatilizing from the subsurface to indoor air within buildings. The baseline estimated risk from this pathway is 9×10^{-6} within Building 854F, and 5×10^{-6} within Building 854A.
2. Manage human health risk resulting from potential incidental ingestion and direct dermal contact with PCB-contaminated surface soil. The baseline estimated risk from this pathway is 7×10^{-5} .
3. Ensure that the risks and hazards estimated in the baseline human health and ecological risk assessments are not exceeded due to changing conditions at the site, and that the remedy remains protective of human health and the environment.
4. Ensure compliance with RAOs.
5. Manage ecological hazard to San Joaquin kit fox and other fossorial vertebrate species of special concern.

Scope:

1. Implement building occupancy and land use restrictions in the vicinity of Building 854F and Building 854A and install warning signs. If sampling of indoor air within Building 854A or 854F indicates that risks currently exceed 10^{-6} or the HI exceeds 1, institute building restrictions or, if building use is again anticipated, install a building ventilation system and operate it whenever the building is occupied.
2. Develop and implement a risk and hazard monitoring and assessment program:
 - Sample indoor ambient air annually for VOCs in Building 854F and Building 854A;
 - Sample surface soil annually for PCBs in the Building 854 complex;
 - Conduct semi-annual wildlife surveys by biologists to evaluate the presence of any species of special concern;
 - Integrate these data into risk assessment calculations to determine any changes in risks and hazards; and
 - Review these data to evaluate compliance with RAOs.
3. Develop and implement Operational Safety Procedures for all remedial actions where risks can be foreseen.

Cost:

Capital Cost: \$18,000

Present Worth O&M Cost: \$221,000

Total Present Worth Cost: \$239,000

4.2.7.4. Building 854 OU—Module D: Ground water and soil vapor extraction and treatment of VOCs and nitrate.**Objectives:**

1. Reduce contaminant concentrations in ground water and the vadose zone.
2. Reduce contaminant mass in the subsurface.
3. Restore and protect beneficial uses of ground water.

Scope:**Source area wellfield**

1. Extract ground water and soil vapor simultaneously from six wells located in the vicinity of the Building 854 Complex.
2. Convert one well from a monitor well (W-854-02).
3. Install five new extraction wells. The screened intervals for the extraction wells would be between 140 and 160 feet bgs.

4. Extract soil vapor (only) from six new wells located in the core complex area. The screened interval for the new wells would be between 10 and 30 feet bgs.
5. Perform six hydraulic tests and four soil vapor extraction tests.
6. Install a total of 500 feet of piping from the extraction wells to the source area treatment system.
7. The estimated flow rate for ground water is 1.0 to 2.0 gpm per well, with a total flow rate of 6 to 12 gpm.
8. Estimated maximum contaminant concentrations in extracted ground water are 260 $\mu\text{g/L}$ TCE and 80 mg/L nitrate. Based on a weighted average from all extraction wells, the estimated contaminant concentrations in treatment system influent are 150 $\mu\text{g/L}$ TCE and 60 mg/L nitrate.
9. The estimated flow rate for soil vapor is 0.8 to 1.0 scfm per well, with a total flow rate of 10 to 12 scfm. The design applied vacuum is 5 to 10 inches of Hg with an estimated radius of influence of 20 to 30 feet per well based on a soil air permeability 10^{-9} cm^2 .
10. The estimated maximum TCE concentration in extracted soil vapor is 20 $\mu\text{g/L}$ ($\text{ppm}_{\text{v/v}}$). Based on a weighted average from all extraction wells, the estimated initial TCE vapor concentration in treatment system influent is 10 to 20 $\mu\text{g/L}$ ($\text{ppm}_{\text{v/v}}$).
11. Treat all extracted ground water by a GWTU (B854-TF1) using aqueous-phase GAC and a fixed-film bioreactor.
12. Treat all extracted soil vapor using vapor-phase GAC.
13. The locations of the components of this remediation module are shown conceptually on Figure 4-11.

Downgradient wellfield

1. Extract ground water (only) from three wells located downgradient of the complex.
2. Convert one existing ground water monitoring well to an extraction well (W-854-03).
3. Install two new extraction wells. The screened interval for the wells would be between 140 and 160 feet bgs.
4. Complete all extraction wells in bedrock (Tnbs_1) of low to moderate estimated hydraulic conductivity.
5. Perform three hydraulic tests on the extraction wells.
6. Install a total of 400 feet of piping from the extraction wells to the downgradient treatment systems.
7. The estimated flow rate for ground water is 0.5 to 1 gpm per well, with a total flow rate of 1 to 2 gpm.
8. Based on a weighted average from all extraction wells, the estimated contaminant concentrations in treatment system influent are 100 $\mu\text{g/L}$ TCE and 40 mg/L nitrate.

9. Treat all extracted ground water by a SWAT (B854-TF2) using aqueous-phase GAC and a fixed-film bioreactor.
10. The locations of the components of this remediation module are shown conceptually on Figure 4-11.

Cost:

Capital Cost: \$1,862,000

Present Worth O&M Cost: \$6,104,000

Total Present Worth Cost: \$7,966,000

4.2.8. Remediation Modules: Building 832 Canyon OU**4.2.8.1. Building 832 Canyon OU—Module A: No further action.****Objectives:**

10. None. Included for comparison.

Scope:

1. No further investigation, sampling, or analyses would be performed.
2. The following COCs are identified for consideration in a no further action module:
 - a) Nitrate in subsurface bedrock has been detected in extremely low concentrations at Buildings 830. No risk or hazard has been identified. No viable remedial technology has been identified. Nitrate in ground water remains a COC.
 - b) HMX in surface soil (Building 830) and subsurface bedrock (Building 832) has been detected in extremely low concentrations. No risk or hazard has been identified. Vadose zone modeling for Building 832 estimates the maximum concentration of HMX to reach ground water would be 0.13 mg/L in 50 years

Cost:

Capital Cost: \$0

O&M Cost: \$0

Total Present Worth Cost: \$0

4.2.8.2. Building 832 Canyon OU—Module B: Monitoring**Objectives:**

7. Periodically collect and analyze ground and surface water samples and perform water level measurements. This module does not include these activities when performed to support the operation and optimization of remedial actions, e.g., the scope and cost of sampling extraction wells.

Scope:

1. Sample and analyze ground water and measure water levels at 33 wells at Building 830 and 18 wells at Building 832.
2. Sample and analyze surface water from one spring.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$2,462,000

Total Present Worth Cost: \$2,462,000

4.2.8.3. Building 832 Canyon OU—Module C: Risk and hazard management.**Objectives:**

1. Manage human health risk resulting from potential inhalation of VOC-contaminated vapor volatilizing from the subsurface to outdoor air near Building 830. The baseline estimated risk from this pathway is 1×10^{-5} .
2. Manage human health risk resulting from potential inhalation of VOC-contaminated vapor volatilizing from the subsurface to indoor air within Building 830. The baseline estimated risk from this pathway is 3×10^{-6} .
3. Manage human health risk resulting from potential inhalation of VOC-contaminated vapor volatilizing from surface water to outdoor air at Spring 3. The baseline estimated risk from this pathway is 7×10^{-5} , with a HI of 2.3.
4. Ensure that the risks and hazards estimated in the baseline human health and ecological risk assessments are not exceeded due to changing conditions at the site, and that the remedy remains protective of human health and the environment.
5. Ensure compliance with RAOs.

Scope:

1. Implement building occupancy and land use restrictions in the vicinity of Building 833 and install warning signs. If sampling of indoor air within Building 833 indicates that risks currently exceed 10^{-6} or the HI exceeds 1, institute building restrictions or, if building use is again anticipated, install a building ventilation system and operate it whenever the building is occupied.
2. Develop and implement a risk and hazard monitoring and assessment program:
 - Sample outdoor ambient air annually for VOCs near Building 830;
 - Sample indoor ambient air annually for VOCs in Building 830;
 - Sample outdoor ambient air annually for VOCs near Spring 3;
 - Integrate these data into risk assessment calculations to determine any changes in risks and hazards; and
 - Review these data to evaluate compliance with RAOs.

3. Develop and implement Operational Safety Procedures for all remedial actions where risks can be foreseen.

Cost:

Capital Cost: \$18,000

Present Worth O&M Cost: \$185,000

Total Present Worth Cost: \$203,000

4.2.8.4. Building 832 Canyon OU—Module D: Ground water and soil vapor extraction and treatment of VOCs, perchlorate, and nitrate at Building 832.**Objectives:**

1. Reduce contaminant concentrations in ground water and the vadose zone.
2. Reduce contaminant mass in the subsurface.
3. Restore and protect beneficial uses of ground water

Scope:**Source area wellfield**

1. Simultaneously extract ground water and soil vapor from 10 wells located in the immediate vicinity of the Building 832 Complex.
2. Convert ten monitor wells (W-832-05, W-832-12, W-832-13, W-832-14, W-832-15, W-832-16, W-832-17, W-832-18, W-832-19, and W-832-20) to complete the extraction well field.
3. The screened intervals of the extraction wells are approximately 7 to 35 feet bgs. All extraction wells are completed in alluvium, fill, and bedrock of low estimated hydraulic conductivity.
4. Perform four hydraulic tests and four soil vapor extraction tests.
5. Install a total of 400 feet of piping from the extraction wells to the source area treatment system.
6. The estimated flow rate for ground water is 0.1 to 1 gpm per well, with a total flow rate of 1 to 3 gpm. Seasonal and yearly fluctuations in ground water are common, and in some years little or no ground water is present.
7. Estimated maximum contaminant concentrations in extracted ground water are 1,300 µg/L TCE, 140 mg/L nitrate, and 14 µg/L perchlorate. Based on a weighted average from all extraction wells, the estimated contaminant concentrations in treatment system influent are 300 µg/L TCE, 90 mg/L nitrate, and 10 µg/L perchlorate.
8. The estimated flow rate for soil vapor is 0.8 to 1.0 scfm per well, with a total flow rate of 8 to 10 scfm. The design applied vacuum is 5 to 10 inches of Hg with an estimated radius of influence of 20 to 30 feet based on a permeability of 10^{-9} cm².

9. The estimated maximum TCE concentration in extracted soil vapor is 30 $\mu\text{g/L}$ ($\text{ppm}_{\text{v/v}}$). Based on a weighted average from all extraction wells, the estimated initial TCE vapor concentration in treatment system influent is 10 to 20 $\mu\text{g/L}$ ($\text{ppm}_{\text{v/v}}$).
10. All extracted ground water from the extraction wells near the Building 832 Complex would be treated by a GWTU (B832-TF1) using aqueous-phase GAC and a fixed-film bioreactor.
11. Treat all extracted soil vapor using vapor-phase GAC.
12. The locations of the components of this remediation module are shown conceptually on Figure 4-12.

Downgradient wellfield

1. Four ground water (only) extraction wells would be located several hundred feet downgradient of the Building 832 Complex.
2. Convert three monitor wells to extraction wells.
3. Install one additional extraction well.
4. The screened intervals of the extraction wells are approximately 25 to 40 feet bgs. All extraction wells would be completed in bedrock of low estimated hydraulic conductivity.
5. Perform four hydraulic tests.
6. A total of 375 feet of piping from the extraction wells to the downgradient treatment systems would be required.
7. Water extracted from the four downgradient ground water (only) extraction wells would be treated using two SWAT units (B832-TF2, B832-TF3) using aqueous-phase GAC and fixed-film bioreactors.
8. At SWAT B832-TF2, the estimated weighted average influent concentrations are 150 $\mu\text{g/L}$ TCE and 75 mg/L nitrate. The estimated flow rate for ground water is 0.1 to 0.3 gpm per well, with a total flow rate of 0.2 to 0.6 gpm. Two extraction wells would be connected to this treatment unit (W-832-01 and W-832-11).
9. At SWAT B832-TF3, the estimated weighted average influent concentrations are 80 $\mu\text{g/L}$ TCE and 70 mg/L nitrate. The estimated flow rate for ground water is 0.1 to 0.3 gpm per well, with a total flow rate 0.2 to 0.6 gpm. Two extraction wells would be connected to this treatment unit (W-832-10 and the new extraction well).
10. The locations of the components of this remediation module are shown conceptually on Figure 4-12.

Cost:

Capital Cost: \$1,642,000

Present Worth O&M Cost: \$8,651,000

Total Present Worth Cost: \$10,293,000

4.2.8.5. Building 832 Canyon OU—Module E: Ground water and soil vapor extraction and treatment of VOCs, perchlorate, and nitrate at Building 830.

Objectives:

1. Reduce contaminant concentrations in ground water and the vadose zone.
2. Reduce contaminant mass in the subsurface.
3. Restore and protect beneficial uses of ground water.

Scope:

Source area wellfield

1. Simultaneously extract ground water and soil vapor from 10 wells located in the immediate vicinity of Building 830.
2. Convert six monitor wells to extraction wells (W-830-30, W-830-34, W-830-49, W-830-19, W-830-22, and W-830-26).
3. Install four additional extraction wells.
4. The screened intervals of the extraction wells would be approximately 10 to 20 feet, and the screened depths would range from 14 to 50 feet bgs. All extraction wells would be completed in alluvium, fill, and/or bedrock of low estimated hydraulic conductivity.
5. Perform six hydraulic tests and four soil vapor extraction tests.
6. Install a total of 400 feet of piping from the extraction wells to the source area treatment system.
7. The estimated flow rate for ground water is 0.1 to 1 gpm per well, with a total flow rate of 1 to 3 gpm.
8. Estimated maximum contaminant concentrations in extracted ground water are 30,000 µg/L TCE, 500 mg/L nitrate, and 22 µg/L perchlorate. Based on a weighted average from all extraction wells, the estimated contaminant concentrations in treatment system influent are 2,000 µg/L TCE, 200 mg/L nitrate, and 10 µg/L perchlorate.
9. The estimated flow rate for soil vapor is 0.8 to 1.0 scfm per well, with a total flow rate of 8 to 10 scfm. The design applied vacuum is 5 to 10 inches of Hg with an estimated radius of influence of 20 to 30 feet based on a permeability of 10^{-9} cm².
10. The estimated maximum TCE concentration in extracted soil vapor is 1,000 µg/L (ppm_{v/v}). Based on a weighted average from all extraction wells, the estimated TCE concentration in treatment system influent is 50 to 100 µg/L (ppm_{v/v}).
11. Treat all extracted ground water from the extraction wells near Building 830 by a GWTU (B830-TF1) using aqueous-phase GAC and a fixed-film bioreactor.
12. Treat all extracted soil vapor using vapor-phase GAC.
13. The locations of the components of this remedial module are shown conceptually on Figure 4-12.

Downgradient wellfield

1. Five ground water (only) extraction wells would be located downgradient of Building 830.
2. Convert three existing ground water monitoring wells to extraction wells (W-830-23, W-830-27, and W-830-28).
3. Install two additional extraction wells.
4. The screened intervals of the extraction wells would be approximately 10 to 20 feet, and the screened depths would range from approximately 25 to 100 feet bgs. All extraction wells would be completed in bedrock of low to moderate estimated hydraulic conductivity.
5. Perform five hydraulic tests.
6. Install a total of 610 feet of piping from the extraction wells to the downgradient treatment systems.
7. Treat water extracted from the five downgradient ground water extraction wells using two SWAT units (B830-TF2, B830-TF3) using aqueous-phase GAC and fixed-film bioreactors.
8. At SWAT B830-TF2, the estimated weighted average influent concentrations are 400 µg/L TCE and 80 mg/L nitrate. The estimated flow rate for ground water is 0.1 to 0.5 gpm per well, with a total flow rate of 0.3 to 1.5 gpm. Three extraction wells would be connected to this treatment unit (W-830-23, W-830-27, and W-830-28).
9. At SWAT B830-TF3, the estimated weighted average influent concentrations are 100 µg/L TCE and 70 mg/L nitrate. The estimated flow rate for ground water is 0.1 to 0.5 gpm per well, with a total flow rate of 0.2 to 1.0 gpm. Two new extraction wells would be connected to this treatment unit.
10. The locations of the components of this remediation module are shown conceptually on Figure 4-12.

Cost:

Capital Cost: \$1,877,000

Present Worth O&M Cost: \$8,761,000

Total Present Worth Cost: \$10,638,000

4.2.8.6. Building 832 Canyon OU—Module F: Downgradient ground water extraction using a siphon with ex situ treatment of VOCs by iron filings.

Objectives:

1. Reduce contaminant concentrations in ground water
2. Reduce contaminant mass in ground water.
3. Control contaminant migration.
4. Restore and protect beneficial uses of contaminated ground water.

Scope:

1. Install two additional monitor wells and four new extraction wells at the siphon location; all wells would be 70 ft deep.
2. Perform five hydraulic tests.
3. Develop a ground water flow and contaminant transport model.
4. Perform bench-scale laboratory tests on ground water from the extraction zone to help select the reactive material and to predict chemical reactions. Perform a field column test at the siphon location to verify results.
5. The estimated concentrations of contaminants on the upgradient side of the siphon are 70 µg/L TCE and 60 mg/L nitrate. The treatment system would be designed to reduce the TCE concentration to levels below detection limits.
6. The capability of iron filings to reduce nitrate concentration is being investigated.
7. Manifold the extraction wells together. Because of flowing artesian conditions at the extraction wells, only a small vacuum would be needed to create a siphon to produce continuous flow from wells. The water from the siphon would flow into an above-grade treatment system filled with iron filings.
8. Convey treated water in a pipe to the culvert at the bottom of the Building 832 Canyon.
9. Perform start-up testing of the system.
10. Conduct monitoring over the 30 year design life of the reactive barrier.
11. Implementing extensive ground water and soil vapor extraction at Building 830 (Module E) may reduce VOC mass in ground water such that contaminant concentrations at the proposed site of the extraction wells would diminish to levels which would render the siphon ineffective.
12. The locations of the components of this remediation module are shown conceptually on Figures 4-12 and 4-13.

Cost:

Capital Cost: \$722,000

Present Worth O&M Cost: \$2,448,000

Total Present Worth Cost: \$3,170,000

4.2.9. Remediation Modules: Building 801 and Landfill Pit 8**4.2.9.1. Building 801 and Landfill Pit 8—Module A: No further action.****Objectives:**

1. None. Included for comparison.

Scope:

1. No further investigation, sampling, or analyses would be performed.
2. The following COCs are identified for consideration in a no further action module:
 - a) VOCs in subsurface bedrock have been detected in extremely low concentrations below the Building 801 Dry Well. No risk or hazard has been identified. No viable remedial technology has been identified to address such extremely low concentrations. This source was closed in 1984. Vadose zone modeling estimates the maximum concentration of TCE to reach ground water in the B801 dry well area would be 15 µg/L in 200 years.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$0

Total Present Worth Cost: \$0

4.2.9.2. Building 801 and Landfill Pit 8—Module B: Monitoring.**Objectives:**

1. Periodically collect and analyze ground water samples and perform water level measurements. This module does not include these activities when performed to support the operation and optimization of remedial actions, e.g., the scope and cost of sampling extraction wells.

Scope:

1. Sample and analyze ground water and measure water levels at six wells.
2. Inspect landfill surface for damage that could compromise the integrity of the landfill, and if such damage is found, arrange for repair.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$535,000

Total Present Worth Cost: \$535, 00

4.2.9.3. Building 801 and Landfill Pit 8—Module C: Waste characterization with contingent monitoring, capping, or excavation of Landfill Pit 8.

Objectives:

1. Control contaminant sources.
2. Prevent potential contamination of ground water.
3. Reduce contaminant mass in the subsurface.
4. Protect beneficial uses of ground water.

Scope:

Waste Characterization of Landfill Pit 8

1. Using a backhoe, excavate two test pits in Landfill Pit 8. Bench or shore each test pit to achieve a depth of 10 feet. Each test pit would be 50 feet long.
2. Collect fill/waste samples from 4 vertical profiles, at 10 ft intervals along the length of each test pit. Collect and analyze samples at depths of 2, 5, and 10 feet from each of the test pits for the following analytes:
 - Tritium
 - STLC metals (including beryllium)
 - TTLC metals (including beryllium)
 - Uranium and thorium isotopes
3. Additionally, analyze samples from a depth of 10 feet at each test pit for each of the following analytes:
 - HE compounds
 - VOCs
4. Backfill the test pits.
5. Auger or use a direct-push rig to drill 8 boreholes within each landfill.
6. Collect samples at depths of 2, 5, and 10 feet for the following analytes:
 - Tritium
 - STLC metals (including beryllium)
 - TTLC metals (including beryllium)
 - Uranium and thorium isotopes
7. Additionally, analyze samples from a depth of 10 feet for each of the following analytes:–
 - HE compounds
 - VOCs

8. Backfill the auger/direct-push holes.
9. Review the analytical data and compare to decision criteria (Section 4.1.2.9.1) to determine whether capping or removal is necessary. If excavation is required, determine the volume of waste that would need to be excavated.
10. Revise estimates for waste classification and total volumes of waste.

Cost:

Capital Cost: \$205,000

Present Worth O&M Cost: \$0

Total Present **Worth Cost: \$205,000**

Capping of Landfill Pit 8

1. Design and construct a multi-layer cap and associated surface water drainage.
2. The estimated area of the cap is 105,000 ft².
3. Perform annual inspections and maintenance of the cap and drainage system.

Cost:

Capital Cost: \$1,017,000

Present Worth O&M Cost: \$154,000

Total Present Worth Cost: \$1,171,000

Excavation of Landfill Pit 8

1. Excavate contaminated firing table debris from Landfill Pit 8. This could range from a small portion to the entire landfill, depending on the amount of material determined to cause significant risk.
2. The estimated depth of excavation is approximately 10 feet.
3. The total estimated volume of excavated material is 24,700 yd³ and is assumed to be low-level radioactive waste which would be disposed of off-site. On-site consolidation or re-consolidation in place may also be feasible and more economical if large volumes are to be extracted.
4. No analytical data are available regarding contaminants that may be present in Landfill Pit 8, but tritium, uranium-238, and metals were possibly disposed in the pit.
5. The locations of the components of this remediation module are shown conceptually on Figures 4-7 and 4-14.

Cost:

Capital Cost: \$1,017,000\$20,872,000

Present Worth O&M Cost: \$0

Total Present Worth Cost: \$20,872,000

Total Module Cost:

\$205,000 (waste characterization only)

\$1,376,000 (waste characterization plus capping)

\$21,077,000 (waste characterization plus excavation with offsite disposal)

4.2.10. Remediation Modules: Building 833 Area**4.2.10.1. Building 833 Area—Module A: No further action.****Objectives:**

None. Included for comparison.

Scope:

1. No further investigation, sampling, or analyses would be performed.
No COCs are identified for consideration of a no further action module.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$0

Total Present Worth Cost: \$0

4.2.10.2. Building 833 Area—Module B: Monitoring.**Objectives:**

1. Periodically collect and analyze ground and surface water samples and perform water level measurements. This module does not include these activities when performed to support the operation and optimization of remedial actions, e.g., the scope and cost of sampling extraction wells.

Scope:

1. Sample and analyze ground water at nine wells.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$661,000

Total Present Worth Cost: \$661,000

4.2.10.3. Building 833 Area—Module C: Risk and hazard management.

Objectives:

1. Manage human health risk resulting from potential inhalation of VOC vapor volatilizing from the subsurface to indoor air within Building 833. The baseline estimated risk from this pathway is 1×10^{-6} , with a HI of less than 1.
2. Ensure that the risks and hazards estimated in the baseline human health and ecological risk assessments are not exceeded due to changing conditions at the site, and that the remedy remains protective of human health and the environment.
3. Ensure compliance with RAOs.

Scope:

1. Implement building occupancy and land use restrictions in the vicinity of Building 833 and install warning signs. If sampling of indoor air within Building 833 indicates that risks currently exceed 10^{-6} or the HI exceeds 1, institute building restrictions or, if building use is again anticipated, install a building ventilation system and operate it whenever the building is occupied.
2. Develop and implement a risk and hazard monitoring and assessment program:
 - Sample indoor ambient air annually for VOCs in Building 833;
 - Integrate these data into risk assessment calculations to determine any changes in risks and hazards; and
 - Review these data to evaluate compliance with RAOs.
3. Develop and implement Operational Safety Procedures for all remedial actions where risks can be foreseen.

Cost:

Capital Cost: \$18,000

Present Worth O&M Cost: \$141,000

Total Present Worth Cost: \$159,000

4.2.10.4. Building 833 Area—Module D: Ground water and soil vapor extraction and treatment of VOCs

Objectives:

1. Reduce human health risk resulting from potential ingestion of contaminated ground water.
2. Prevent continued contamination of ground water.
3. Achieve contaminant mass removal.
4. Restore or protect beneficial uses of ground water.

Scope:

1. Ground water and soil vapor would be extracted simultaneously from two wells located in the vicinity of Building 833.
2. Both extraction wells would be converted monitor wells (W-833-03 and W-833-12).
3. The screened intervals for the wells are between 20 and 30 feet bgs. The extraction wells would be completed in a shallow perched water-bearing zone of low estimated hydraulic conductivity.
4. Soil vapor (only) would be extracted from four new wells located in the vicinity of Building 833. The screened interval for the new wells would be between 30 and 40 feet bgs. The wells would be completed in fine-grained material with low estimated hydraulic conductivity below the perched water-bearing zone.
5. Two hydraulic tests and two soil vapor extraction tests would be performed.
6. A total of 170 feet of piping from the extraction wells to the treatment systems would be required.
7. The estimated flow rate for ground water is 0.1 to 0.5 gpm per well, with a total flow rate of 0.2 to 1.0 gpm. Seasonal and yearly fluctuations in ground water are common, and in some years little or no ground water is present.
8. Estimated maximum contaminant concentration in extracted ground water is 1,100 $\mu\text{g/L}$ TCE. Based on a weighted average from all extraction wells, the estimated TCE concentration in treatment system influent is 500 to 1,000 $\mu\text{g/L}$.
9. The estimated flow rate for soil vapor is 0.8 to 1.0 scfm per well, with a total flow rate of 10 to 12 scfm. The design applied vacuum is 5 to 10 inches of Hg with an estimated radius of influence of 20 to 30 ft per well based on a soil air permeability of 10^{-9} cm^2 .
10. The estimated maximum TCE concentration in extracted soil vapor is 40 to 50 $\mu\text{g/L}$ ($\text{ppm}_{\text{v/v}}$). Based on a weighted average from all extraction wells, the estimated initial TCE vapor concentration in treatment system influent is 20 to 30 $\mu\text{g/L}$ ($\text{ppm}_{\text{v/v}}$).
11. All extracted ground water would be treated by one GWTU (B833-TF1) using aqueous-phase GAC.
12. All extracted soil vapor would be treated using vapor-phase GAC.
13. The locations of the components of this remediation module are shown conceptually on Figure 4-15.

Cost:

Capital Cost: \$803,000

Present Worth O&M Cost: \$2,633,000

Total Present Worth Cost: \$3,436,000

4.2.11. Remediation Modules: Building 845 Firing Table and Landfill Pit 9

4.2.11.1. Building 845 Firing Table and Landfill Pit 9—Module A: No further action.

Objectives:

1. None. Included for comparison.

Scope:

1. No further investigation, sampling, or analyses would be performed.
2. The following COCs are identified for consideration of a no further action module:
 - a) Uranium-238 in subsurface soil below the Building 845 firing table. The maximum concentration of uranium-238 is 1.2 pCi/g. Vadose zone modeling estimates the maximum activity of total uranium to reach ground water would be 42 pCi/L, in 2,750 years, and that it will be about 2,000 years before the MCL is exceeded.
 - b) HMX in subsurface soil below the Building 845 firing table. The maximum concentration of HMX is 0.054 mg/kg. Vadose zone modeling estimates the maximum concentration of HMX to reach ground water would be 0.014 mg/L, in 260 years.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$0

Total Present Worth Cost: \$0

4.2.11.2. Building 845 Firing Table and Landfill Pit 9—Module B: Monitoring.

Objectives:

1. Periodically collect and analyze ground and surface water samples and perform water level measurements, although no COCs have been identified in ground water.

Scope:

1. Sample and analyze ground water and measure water levels at four wells.
2. Sample and analyze surface water from one spring.
3. Inspect landfill surface for damage that could compromise the integrity of the landfill and if such damage is found, arrange for repair.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$488,000

Total Present Worth Cost: \$488,000

4.2.11.3. Building 845 Firing Table and Landfill Pit 9—Module C: Waste characterization with contingent monitoring, capping, or excavation of Landfill Pit 9.

Objectives:

1. Control contaminant sources.
2. Prevent potential contamination of ground water.
3. Reduce contaminant mass in the subsurface.
4. Protect beneficial uses of ground water.

Scope:

Waste Characterization of Landfill Pit 9

1. Using a backhoe, excavate two test pits in Landfill Pit 9. Bench (or shore) each test pit to achieve a depth of 10 feet. Each test pit would be 50 feet long.
2. Collect fill/waste samples from 4 vertical profiles, spaced at 10 ft intervals along the length of each test pit. Collect and analyze samples at depths of 2, 5, and 10 feet from each of the test pits for the following analytes:
 - Tritium
 - STLC metals (including beryllium)
 - TTLC metals (including beryllium)
 - Uranium and thorium isotopes
3. Additionally, analyze samples from a depth of 10 feet at each test pit for each of the following analytes:
 - HE compounds
 - VOCs
4. Backfill the test pits.
5. Auger or use a direct-push rig to drill 8 boreholes within each landfill.
6. Collect samples at depths of 2, 5, and 10 feet for the following analytes:
 - Tritium
 - STLC metals (including beryllium)
 - TTLC metals (including beryllium)
 - Uranium and thorium isotopes
7. Additionally, analyze samples from a depth of 10 feet for each of the following analytes:
 - HE compounds
 - VOCs

8. Backfill the auger/direct-push holes.
9. Review the analytical data and compare to regulatory standards to determine whether capping or removal is necessary. If excavation is required, determine the volume of waste that would need to be excavated (see decision process, Section 4.1.2.9.1).
10. Revise estimates for waste classification and total volumes of waste.

Cost:

Capital Cost: \$205,000

Present Worth O&M Cost: \$0

Total Present Worth Cost: \$205,000

Capping of Landfill Pit 9

1. Design and construct a multi-layer cap and associated surface water drainage.
2. The estimated area of the cap is 20,000 ft².
3. Perform annual inspections and maintenance of the cap and drainage system.

Cost:

Capital Cost: \$550,000

Present Worth O&M Cost: \$154,000

Total Present Worth Cost: \$704,000

Excavation of Landfill Pit 9

1. Excavate contaminated firing table debris from Landfill Pit 9. This could range from a small portion to the entire landfill, depending on whether the amount of material determined to cause significant risk.
2. The estimated depth of excavation is approximately 10 feet.
3. The total estimated volume of excavated material is 7,400 yd³, which is assumed to be low-level radioactive waste.
4. No analytical data are available on contaminants that may be present in Landfill Pit 9, but tritium, uranium-238, and metals were possibly disposed in the pit.
5. The locations of the components of this remediation module are shown conceptually on Figures 4-7 and 4-16.

Cost:

Capital Cost: \$6,372,000

Present Worth O&M Cost: \$0

Total Present Worth Cost: \$6,372,000

Total Module Cost:

\$205,000 (waste characterization only)

\$909,000 (waste characterization plus capping)

\$6,577,000 (waste characterization plus excavation with offsite disposal)

4.2.12. Remedial Modules: Building 851 Firing Table**4.2.12.1. Building 851 Firing Table—Module A: No further action.****Objectives:**

1. None. Included for comparison.

Scope:

1. No further investigation, sampling, or analyses would be performed.
2. The following COCs are identified for consideration in a no further action module:
 - a) TCE has been detected at a maximum concentration of 0.0003 mg/kg in subsurface bedrock below the Building 851 firing table. No risk or hazard has been identified. No viable remedial technology has been identified to address such extremely low concentrations.
 - b) Uranium-238 has been detected at a maximum concentration of 11 pCi/g in subsurface bedrock below the Building 851 firing table. Vadose zone modeling estimates the maximum activity of total uranium under the firing table to reach ground water would be 786 pCi/L in 4,600 years. The modeling indicates that total uranium will not exceed the MCL of 20 pCi/L in ground water for over 3,000 years.
 - c) Uranium-238 has been detected at a maximum concentration of 14.11 pCi/g in surface soil adjacent to the Building 851 firing table. Vadose zone modeling estimates the maximum activity of total uranium to reach ground water from soil adjacent to the firing table would be 24 pCi/L, in 5,000 years, and it will be about 4,600 years before the MCL is exceeded.
 - d) Cadmium has been detected at a maximum concentration of 9 mg/kg in surface soil adjacent to the Building 851 firing table. Vadose zone modeling estimates the maximum concentration to reach ground water would be 0.0024 mg/L in 20,000 years.
 - e) Copper has been detected at a maximum concentration of 79 mg/kg in surface soil adjacent to the Building 851 firing table. Vadose zone modeling estimates the maximum concentration to reach ground water would be 0.054 mg/L in 20,000 years.
 - f) Zinc has been detected at a maximum concentration of 360 mg/kg in surface soil adjacent to the Building 851 firing table. Vadose zone modeling estimates the

maximum concentration to reach ground water would be 0.041 mg/L in 10,000 years.

- g) RDX has been detected at a maximum concentration of 0.131 mg/kg in surface soil adjacent to the Building 851 firing table. Vadose zone modeling estimates the maximum concentration to reach ground water would be 2.5 µg/L in 400 years.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$0

Total Present Worth Cost: \$0

4.2.12.2. Building 851 Firing Table—Module B: Monitoring.

Objectives:

1. Periodically collect and analyze ground and surface water samples and perform water level measurements. This module does not include these activities when performed to support the operation and optimization of remedial actions, e.g., the scope and cost of sampling extraction wells.

Scope:

1. Sample and analyze ground water and measure water levels at five wells.
2. Sample and analyze surface water from one surface water drainage.

Cost:

Capital Cost: \$0

Present Worth O&M Cost: \$530,000

Total Present Worth Cost: \$530,000

4.2.12.3. Building 851 Firing Table—Module C: Ground water extraction and treatment of uranium-238.

Objectives:

1. Reduce contaminant concentrations in ground water.
2. Reduce contaminant mass in ground water.
3. Restore and protect beneficial uses of ground water.

Scope:

1. Extract ground water from a total of four wells.
2. Convert two monitor wells to extraction wells (W-851-07 and W-851-08).
3. Install two additional extraction wells.

4. The screened intervals of the extraction wells would be approximately 145 to 180 feet bgs. All extraction wells would be completed in bedrock of moderate estimated permeability.
5. Perform four hydraulic tests.
6. Install a total of 1,000 feet of piping from the extraction wells to the treatment system.
7. The estimated flow rate for ground water is 0.2 to 1.0 gpm per well, with a total flow rate of 1 to 3 gpm.
8. Based on a weighted average from all extraction wells, the estimated uranium-238 activity in treatment system influent is about 5 pCi/L.
9. All extracted ground water would be treated by a SWAT (B851-TF1) using ion exchange for uranium-238.
10. The locations of the components of this remediation module are shown conceptually on Figure 4-17.

Cost:

Capital Cost: \$593,000

Present Worth O&M Cost: \$3,075,000

Total Present Worth Cost: \$3,668,000